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# CASE FILE

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TITLE

SCOUT FIRST STAGE FLIGHT CHARACTERISTICS

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## ABSTRACT

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<p>An investigation has been conducted to determine the Scout vehicle aerodynamic and control effectiveness characteristics from flight data. Eleven recent Scout flights were analyzed and the aerodynamic moment coefficients and jet vane and control tip lift effectiveness were adjusted such that the flight measured control surface deflections and vehicle trajectory parameters could be accurately simulated. Flight data indicated (a) reduced subsonic and transonic aerodynamic stability compared with wind tunnel test data of a Scout model with no protuberances, (b) an increased supersonic pitching moment at zero angle of attack, and (c) reduced jet vane lift effectiveness. Incorporation of the revised data gives good correlation between simulated and measured control deflections and flight path and heading angles.</p>				

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## 1.0 SUMMARY

A detailed analysis of the Scout first stage flight characteristics has been made. Flight data indicated significant deviations from predicted characteristics. Pitch and yaw moments have been computed for 11 recent Scout flights and were correlated with control surface effectiveness, aerodynamic pitching and yawing moment coefficients, and thrust misalignment. This flight data indicated a reduction in the subsonic and transonic static stability, a reduction in jet vane effectiveness, an increase in fin tip effectiveness transonically and a larger pitching moment at zero angle of attack supersonically caused by a negative normal force aft of the center of mass. These characteristics were adjusted and used in the post-flight trajectory simulation program for the 11 vehicles analyzed. These adjustments significantly improved the simulation of the telemetered pitch and yaw control surface deflections as well as the radar tracking of the flight path angle and heading angle.

## 2.0 INTRODUCTION

The Scout vehicle configuration is shown in Figure 1. The motor stack consists of an Algol II first stage, Castor second stage, X-259 Antares third stage, and an X-258 or FW4S fourth stage. The heatshield has a 34-inch maximum diameter with a nose at Scout station -25. Various protuberances consisting of antennas, wiring tunnels, launch fittings and fairings, and fairings about upper stage reaction control motors and spin motors are attached to the exterior of the transition sections and motor cases. Flight trajectory parameters, Mach number, dynamic pressure, center of gravity and moment of inertia time histories for this configuration do not differ appreciably from flight to flight. Typical time histories for these parameters are shown in Figure 2.

There has always been a difficulty in simulating the Scout vehicle first stage attitude and flight path history with predicted aerodynamics and

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control surface characteristics. Post-flight analysis of the first stage control surface deflections and trajectory using measured wind profiles and post-flight motor data indicated a considerable difference between the predicted vehicle characteristics and the actual characteristics.

As part of the post-flight analysis of each Scout vehicle the pitching and yawing moments acting about the vehicle center of mass were calculated using the predicted aerodynamic data presented in Reference 1, the measured meteorological data, telemetry data and radar tracking data. The computed control moments and aerodynamic moments did not fully account for the observed vehicle trim attitude. The pitch and yaw residual moments were calculated and included in the post-flight simulation. These artificially provided the simulation with the necessary vehicle trim attitude. Although vehicle control deflections could be simulated this way, the flight path and heading angles were not accurately simulated. These residual or "unexplained" moments which are included in the final flight reports (eg see references 2 through 12) represent a combination of flight data inaccuracy, vehicle thrust vector misalignment, and the differences between the predicted and actual vehicle aerodynamic and control characteristics.

As more Scout vehicles were flown and analyzed it became obvious that the residual moments or deviations were not random in occurrence. Pitching moments indicated a time history very similar in shape (but of opposite sign and lower magnitude) to the control moments during the first pitch program step. Transonically large pitch and yaw residual moments appeared which had the opposite sign of the aerodynamic restoring moment. Supersonically, pitch-up moments were calculated which varied with the dynamic pressure.

More evidence was gathered and an investigation was made to determine the most likely source of the observed deviations. The results of that investigation are presented in Reference 13. They indicate an error in

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the jet vane performance data, a reduced aerodynamic stability transonically and a possible increase in the supersonic pitching moment at zero angle of attack.

Subsequent to the analysis performed in Reference 13, the basic jet vane data was reviewed and found to be in error and corrected. The revised data is presented in Reference 14. A supersonic wind tunnel test of a 1/15 scale model of the Scout configuration using a 34-inch diameter heatshield with a nose at station -10 with protuberances has been made under Work Item 14 of Contract NAS1-3915. This test data, presented in Reference 15, was reviewed during the current analysis.

Subsequent to the investigation of Reference 13, and the revision of jet vane data (Reference 14), a computer routine was developed to calculate the first stage moment disturbances. Several additional potential sources of moments have been included in the calculations including jet damping, mass imbalance and aeroelastic induced thrust misalignment. A description of this calculation method and the routine description is presented in Reference 16.

More recent post-flight analyses utilizing revised jet vane data indicate the same trends in residual moments although the magnitude has been considerably reduced during the first commanded rate of the pitch program and slightly reduced in the supersonic region.

The purpose of the current investigation is to define as closely as possible the vehicle characteristics as observed from flight data. The method consists of correlation of calculated pitch and yaw residual moments with aerodynamic angle, control surface deflections, dynamic pressure, Mach number, and thrust level. Effective pitching and yawing moment coefficients, jet vane effectiveness, control tip effectiveness and thrust misalignment were computed for 11 recent Scout flights. The various characteristics were adjusted such that the residual moments were reduced to a low magnitude with a random variation from vehicle to vehicle. Reasons for the discrepancies

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between actual and predicted characteristics were sought when it was practical to do so. The post-flight trajectory simulations for these 11 vehicles were computed with the adjusted characteristics to determine the accuracy through the simulation of flight path and heading angle history and control surface deflections.

### 3.0 DISCUSSION

The analysis of the first stage pitching and yawing moment disturbances, presented in Reference 13, defined the probable areas where the flight characteristics did not agree with predicted characteristics. These included jet vane effectiveness, aerodynamic stability, pitching moment at zero angle of attack and thrust misalignment. Several other sources of moments were investigated such as vehicle alignment, aeroelastic induced thrust misalignment, jet damping and mass imbalance. These were investigated and proved to be either random or relatively minor in importance. The recommendations presented in Reference 13 included (1) accurate instrumentation of Algol static firings to determine thrust misalignment (2) pressure instrumenting the Base "A" fins for investigation of the pitch-up at launch phenomena, (3) review the jet vane test setup and data (4) computation of the effects of altitude on jet vane effectiveness (5) wind tunnel testing at transonic and supersonic Mach numbers including the protuberances to evaluate the effects of combined angles of attack and sideslip and rocket exhaust pluming (6) evaluate vehicle tooling, assembly fixtures and alignment measurements, (7) utilize a wind measurement procedure to give the wind profile data at launch time and (8) conduct a study of flight data to determine the remaining uncertainties in flight characteristics.

Since that investigation was performed the jet vane test data was reviewed and found to be in error due to data reduction errors and failure to check the alignment of the jet vane relative to the nozzle centerline. The

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effects of altitude on jet vane performance were estimated. This revised jet vane data is presented in Reference 14. A limited wind tunnel test of a model of a Scout configuration utilizing a 34-inch diameter heatshield with nose at station -10 with protuberances has been made under Work Item 14 of contract NAS1-3915. Pertinent data from this test has been used in this investigation. A random selection of vehicle "B", "C", and "D" section assemblies was checked to determine if these sections were being built in such a way as to give the vehicle a consistently bent shape. No bias was indicated.

## 3.1 CALCULATED FLIGHT CHARACTERISTICS

3.1.0 The investigation of the first stage flight characteristics involved analysis of the data from Scout vehicles S-137, S-141, S-147, S-148, S-149, S-150, S-151, S-152, S-154, S-155, and S-156. Pertinent flight data for these vehicles is presented in references 2 through 12. The residual moments (moments which were not explained with the predicted vehicle characteristics) were calculated and are presented in Figures 3 through 13. The residual moments were correlated with Mach number, dynamic pressure, angles of attack and sideslip and control surface deflections to determine the apparent jet vane effectiveness, control tip effectiveness, and pitch and yaw aerodynamic moment coefficients. These are discussed in the following paragraphs.

### 3.1.1 Jet Vane Lift Effectiveness

During the first commanded rate of the pitch program, the Scout control surfaces undergo large amplitude deflections in pitch. On most flights the peak deflections reach angles of 10 to 20 degrees in response to the first step in pitch program rate. During this period the residual pitching moments indicate a time history very similar to the control surface deflection. The lift effectiveness of the jet vanes can therefore be easily detected. The accuracy of these calculations are greatest during this time period since the fin control tip and aerodynamic moments are at a minimum due to the low dynamic

pressure.

The percentage reduction in jet vane lift effectiveness derived from flight data during this time period was applied for the total burning time. The results are shown in Figure 14. On one of the two jet vane tests (Algol II-B-31 Test Firing) motor side forces were measured. By correlating the side force data to the jet vane deflection history a lower jet vane effectiveness was computed. This is also shown in Figure 14. The analysis of flight characteristics indicates a jet vane lift greater than that determined from static test side force measurement but less than the sting balance data upon which the current predictions are based. The jet vane lift data derived from flight data is assumed to be the most accurate available.

### 3.1.2 Fin Tip Lift Effectiveness

The fin tip lift provides a rather small contribution to control early in the flight. The tip effectiveness increases rapidly as the Mach number approaches 1.0 and remains relatively high until after peak dynamic pressure occurs. The wind tunnel test data from which fin tip lift has been extracted has been reviewed. This test data shows a considerable degree of scatter as shown in Figure 15. The fin tip effectiveness was adjusted as a reasonable fairing of the wind tunnel results.

### 3.1.3 Aerodynamic Pitching and Yawing Moment Coefficients

Utilizing the adjusted jet vane and fin tip effectiveness noted in the preceding paragraphs, the pitching and yawing moments were recomputed. From these, the effective pitching and yawing aerodynamic coefficients were calculated for the eleven vehicles and were correlated with angles of attack and sideslip and Mach number. Assuming that the pitch and yaw stability derivatives are equal the pitching and yawing moment coefficients at zero aerodynamic angle were calculated at Mach numbers of 0.5, 0.8, 1.0, 1.2, 1.5, 2.0, 2.5, 3.0 and 3.5. The best fit of the pitching and yawing moment

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coefficients at zero aerodynamic angle are shown in Figure 16. The flight data indicates a reduced subsonic pitch-up moment but a significantly increased supersonic pitch-up moment compared to the prediction (Reference 1). Flight data also shows a relatively low yawing moment coefficient at zero angle of sideslip in the supersonic region. This is also shown in Figure 16.

The large change in supersonic pitching moment at zero angle of attack was investigated. The vehicle protuberances are the most likely source of aerodynamic asymmetry. The effect on pitching moment of the Base "A" launch fitting fairings was estimated supersonically. There are two of these fairings on Base "A" located adjacent to the upper surface of the two pitch fins. The shock pattern from these protuberances increases the pressure on the upper fin surface resulting in a pitch-up moment to the vehicle. The estimation of this contribution to the pitching moment coefficient at zero angle of attack is presented in Figure 16.

The wind tunnel test data presented in Reference 15 included runs at a Mach number of 2.8 both with and without protuberances. The effect of protuberances on the pitching moment at zero angle of attack is presented in Figure 16 and shows a close agreement with that extracted from flight data.

The effect of each vehicle protuberance is not known and would require wind tunnel measurements with a buildup of protuberances one at a time. Scout vehicles S-160, S-161, and S-162 will have dummy Base "A" launch fitting fairings installed on the lower side of Base "A" to balance out the effects of the standard fairings. Analysis of flight data from these three vehicles may help to define their contribution to vehicle pitching moment at zero angle of attack.

The pitch and yaw stability derivatives were also determined from flight data. The best fit of the pitching and yawing moment coefficient slope at each Mach number was determined. The results are compared with the predicted



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data from Reference 1 in Figure 17. The stability is considerably less than predicted subsonically and transonically. Supersonically the flight data indicates slightly greater than predicted stability. In each case the rigid vehicle stability derivatives are shown. These were obtained by incrementing the flight results by the predicted aeroelastic effects. The effective center of pressure is shown in Figure 18. This is based on the pitching moment coefficient slope presented in Figure 17 and the predicted aerodynamic normal force coefficient slope from Reference 1.

The source of the discrepancy between the predicted and apparent pitch and yaw stability derivatives has not been determined. There has not been any wind tunnel testing of the complete Scout configuration with the 34-inch diameter heatshield with nose at station -25 with the protuberances on. A wind tunnel test of the current Scout configuration with protuberances including the effects of combined angles of attack and sideslip would be required to help determine the source. ~~The jet plume may have an effect on vehicle stability but it is expected to be insignificant due to the low jet pressure ratio in flight.~~

## 3.2 EVALUATION OF ADJUSTMENTS ON VEHICLE CHARACTERISTICS

The adjustments in vehicle characteristics presented in Section 3.1 were used to recompute the pitch and yaw residual moments and in simulating the control surface deflections and trajectory parameters.

### 3.2.1 Comparison of Residual Moments

The residual moments for the eleven vehicles analyzed are compared with those computed with unadjusted characteristics in Figures 3 through 13. The use of the adjusted characteristics significantly reduces the pitch and yaw residual moments in most cases. The pitching and yawing residual moments which remain are essentially random from vehicle to vehicle.

### 3.2.2 Comparison of Trajectory and Control Surface Deflection

The adjustments in vehicle characteristics were also used in a first stage trajectory and control system simulation using the NEMAR routine described in Reference 17. The post-flight measured winds and other pertinent data used in the simulations is presented in References 2 through 12. The pitch and yaw control surface deflections are compared with both the telemetered deflections and those simulated without adjustments in Figures 3 through 13. The use of the adjustments significantly improves correlation with flight data. Differences in the pitch and yaw moments and in the simulation of control surface deflections reflect for the most part instrumentation and data reduction accuracy, wind uncertainties, random vehicle misalignments, mass unbalance and thrust misalignment.

A comparison of the flight path angle histories in Figures 3 through 13 shows a trend toward higher simulated flight path angle histories after 20 to 30 seconds of flight when the control surface deflections are closely simulated. This discrepancy is a result of defining the change in vehicle aerodynamics in terms of moment coefficients without altering the normal and side force coefficients.

A limited analysis of this flight path angle deviation was performed on vehicle S-150. As shown in Figure 8a, the simulation of pitch control deflection was very close but as shown in Figure 19 the difference between simulated and actual flight path angle increases after 20 seconds flight time. The high amplitude wiggles reflect radar data scatter. The flight path angle deviation was smoothed as shown in this figure and used to estimate the vehicle normal force time history. A downward normal force of about 800 pounds between 25 and 45 seconds flight time would be required. This normal force was used in the simulation for vehicle S-150. The deviation from radar measured flight path angle was very small as shown in Figure 19. Simulated control surface deflections remained unchanged.

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The computed angle of attack is essentially zero between 22 and 35 seconds flight time for vehicle S-150. The incremental normal force presented in Figure 19 is most probably associated with the pitching moment at zero angle of attack. To provide pitch-up moment supersonically the downward force would be located aft of the center of gravity. Vehicle protuberances aft of this point include wiring tunnel covers on the "B" section flare, the forward launch ring fitting, the wiring tunnels on the Algol motor with flared ends on Base "A" and the Base "A" launch fitting fairings. All of these protuberances are arranged symmetrically about the pitch plane but are all on the upper side of the vehicle.

A comparison of the heading angle histories in Figures 3 through 13 does not show a pattern as did flight path angle, indicating very little if any side force at zero angle of sideslip. The yawing moment at zero sideslip angle is also very low.

### 3.2.3 Influence of Wind Variability and Thrust Misalignment

The influence of wind variability and thrust vector misalignment on the control surface deflection history and vehicle flight path was evaluated.

Wind profiles are usually measured several hours before and after each Scout launch. Since the winds used in the simulation may be measured several hours before or after launch, deviations from those experienced in flight will occur. To evaluate these deviations the trajectory simulation of vehicle S-152 was made with both the pre-launch and post-launch measured winds. These wind profiles shown in Figure 20 represent a typical time variation. The simulated control surface deflections and flight path history are compared with flight data in Figure 10. Control surface deflections may vary several degrees due to the differences in the two wind profiles. The changes in heading angle for both wind profiles are not very significant when the adjusted aerodynamic

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characteristics are used.

The effect of thrust vector misalignment was evaluated with vehicle S-141 which apparently experienced 0.20 degrees thrust misalignment in the yaw plane. A comparison of the simulated yaw control surface deflections and heading angle with and without 0.20 degree thrust misalignment is presented in Figure 4. The simulated yaw control surface deflections and heading angle are considerably different from flight data without thrust misalignment with or without the adjusted aerodynamic characteristics. The simulation including the adjusted characteristics plus 0.20 degrees of yaw thrust misalignment is very close to flight data both in control surface deflections and heading angle. During the analysis several other vehicles were analyzed with a thrust misalignment. The analysis indicated that thrust misalignment angles of much less than 0.20 degrees can account for many of the deviations between simulated trajectory parameters and flight data when the aerodynamic characteristics are adjusted.

#### 4.0 CONCLUSIONS AND RECOMMENDATIONS

The analysis of the Scout vehicle flight characteristics shows (1) aerodynamic stability is less than predicted in the subsonic and transonic region, (2) the jet vane lift effectiveness is lower than predicted, (3) the vehicle protuberances contribute to the pitching and yawing moment coefficients at zero aerodynamic angle, (4) the control fin tip effectiveness is higher than predicted in the transonic region, (5) differences in wind profiles before and after launch can noticeably influence the simulation of vehicle control surface deflections, flight path angle and heading angle, (6) the Algol motor has a thrust misalignment of as much as 0.20 degrees and this can significantly influence the control surface deflections and trajectory parameters and (7) the vehicle alignment buildup deviations vary randomly from vehicle to vehicle.

The post-flight trajectory calculation of the first stage with the adjusted aerodynamic and control characteristics provides a significantly

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improved simulation of flight path angle, heading angle and control surface deflections. Flight path angle simulation can be significantly improved by adding a downward normal force at zero angle of attack.

The following action is recommended for the current Scout configuration: (1) revise the vehicle aerodynamic and control characteristics to reflect the data presented in this report and use the revised characteristics in the Scout pre- and post-flight analyses, (2) estimate the required change in the vehicle aerodynamic running load distribution to agree with the pitch and yaw stability derivatives obtained from flight data, and (3) estimate the incremental normal force at zero angle of attack based on the eleven vehicles considered in this analysis and include in the Scout pre- and post-flight analysis.

In addition, future Scout configuration changes which affect external lines should undergo wind tunnel testing to accurately define the pitch, yaw and roll stability characteristics and the effects of protuberances. Such wind tunnel tests could include model buildup of protuberances one at a time to define the individual effects. Test at various angles of attack over a range of roll angles should be done to define the effects of combined angles of attack and sideslip on pitch, yaw and roll stability.

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### References

1. "Aerodynamic Design Data Report" LTV Aerospace MSD Report AST/E1R-12431, 20 February 1961, revised 31 October 1966.
2. "NASA Scout S-137 Final Flight Report" LTV Aerospace MSD Report No. 3-30000/5R-22 dated 11 March 1965.
3. "Scout S-141C Final Flight Report" LTV Aerospace MSD Report No. 3-30000/6R-15 dated 18 May 1966.
4. "Scout S-147C Final Flight Report" LTV Aerospace MSD Report No. 3-30000/6R-24 dated 16 September 1966.
5. "Scout S-148C Final Flight Report" LTV Aerospace MSD Report No. 3-30000/6R-30 dated 4 November 1966.
6. "Scout S-149C Final Flight Report" LTV Aerospace MSD Report No. 3-30000/6R-28 dated 31 October 1966.
7. "Scout S-150C Final Flight Report" LTV Aerospace MSD Report No. 3-30000/7R-3 dated 23 January 1967.
8. "Scout S-151C Final Flight Report" LTV Aerospace MSD Report No. 3-30000/7R-7 dated 17 March 1967.
9. "Scout S-152C Final Flight Report" LTV Aerospace MSD Report No. 3-32000/7R-144 dated 4 August 1967.
10. "Scout S-154C Final Flight Report" LTV Aerospace MSD Report No. 3-32000/7R-155 dated 5 September 1967.
11. "Scout S-155C Final Flight Report" LTV Aerospace MSD Report No. 3-32000/7R-148 dated 21 August 1967.
12. "Scout S-156C Final Flight Report" LTV Aerospace MSD Report No. 3-32000/7R-182 dated 23 October 1967.
13. "Scout First Stage Moment Disturbance Study" LTV Aerospace MSD Report 23.287, 15 July 1966.
14. "Algol II Jet Vane Performance" LTV Aerospace MSD 23-DIR-431, Revision A, 29 March 1967.
15. "Static Force Tests on a 0.0667 Scale Scout Force Model Over the Supersonic Mach Range of 1.61 to 2.80 (U)" LTV Aerospace VAD Report H3WT Test 263, dated August 1967.
16. "First Stage Moment Disturbance Routine - LVVZ-45" LTV Aerospace MSD Report 23.307, 18 November 1966.
17. "Near Earth Mission Analysis Trajectory Routine, LVVC-27" LTV Aerospace MSD Report No. 00.251 dated 4 October 1963, revised 4 January 1968.

FIGURE 1  
SCOUT CONFIGURATION

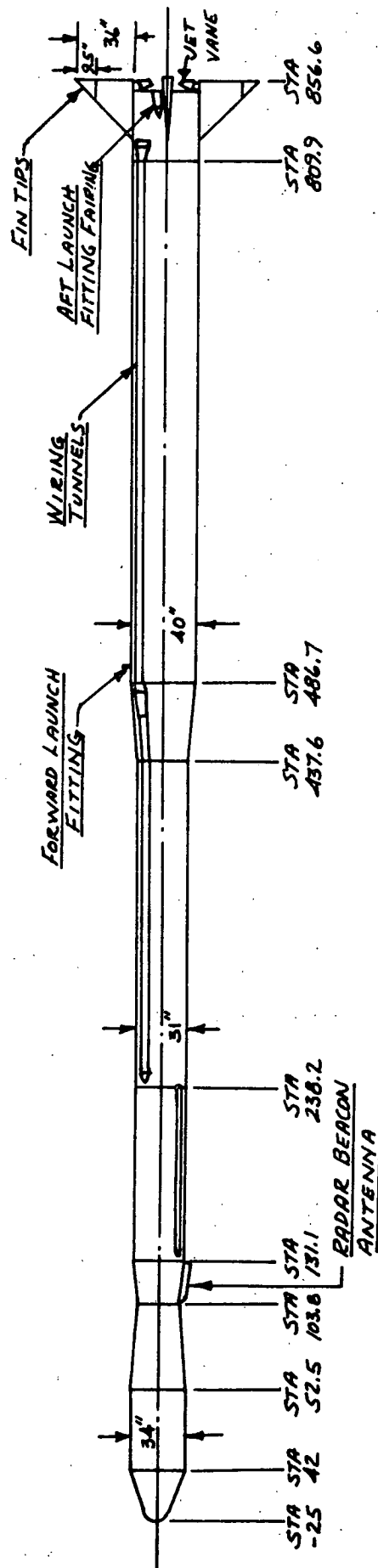


FIGURE 2  
 TYPICAL FLIGHT PARAMETER TIME HISTORY  
 VEHICLE S-150

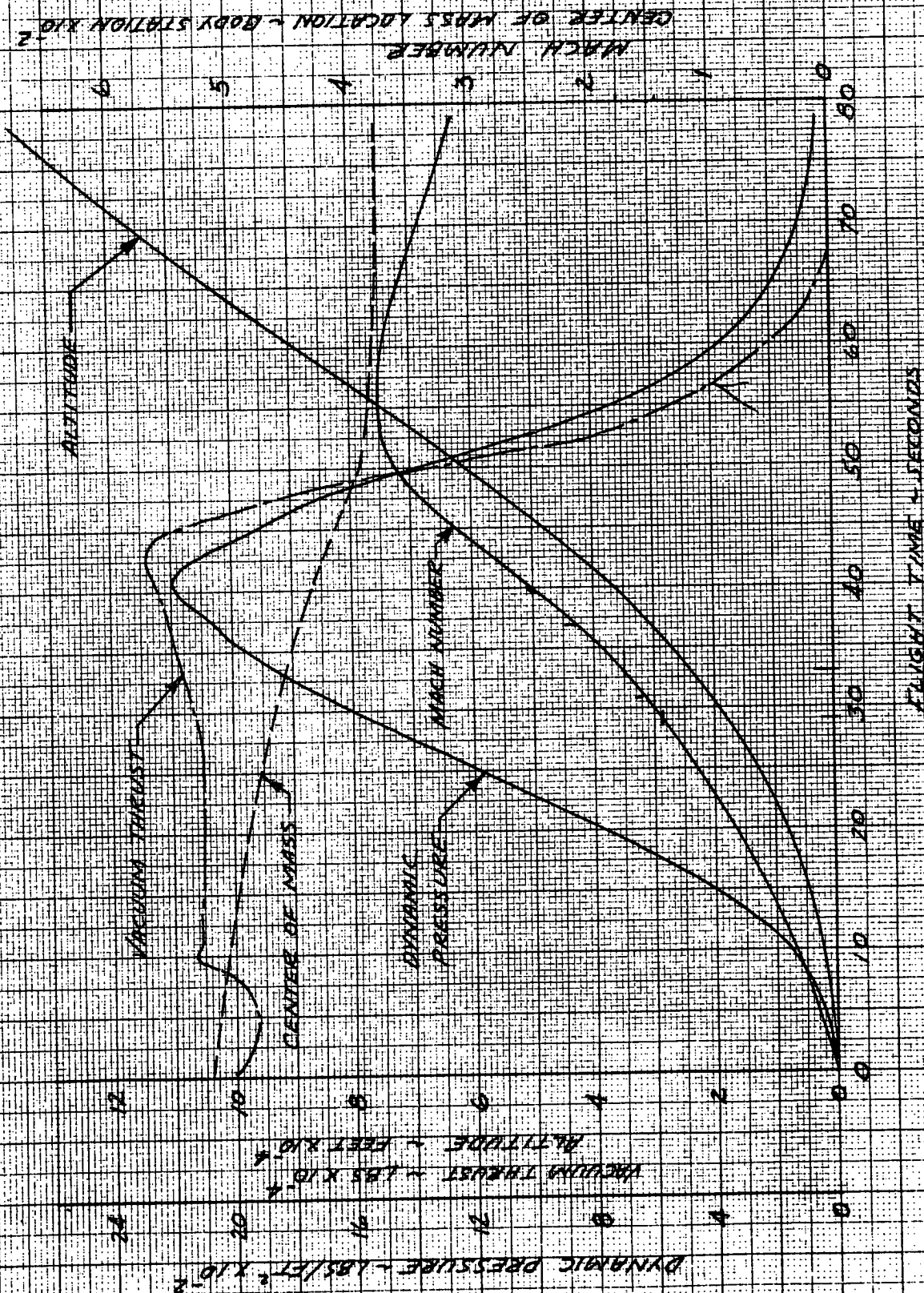




FIGURE 3a  
 S-137 FLIGHT DATA COMPARISON

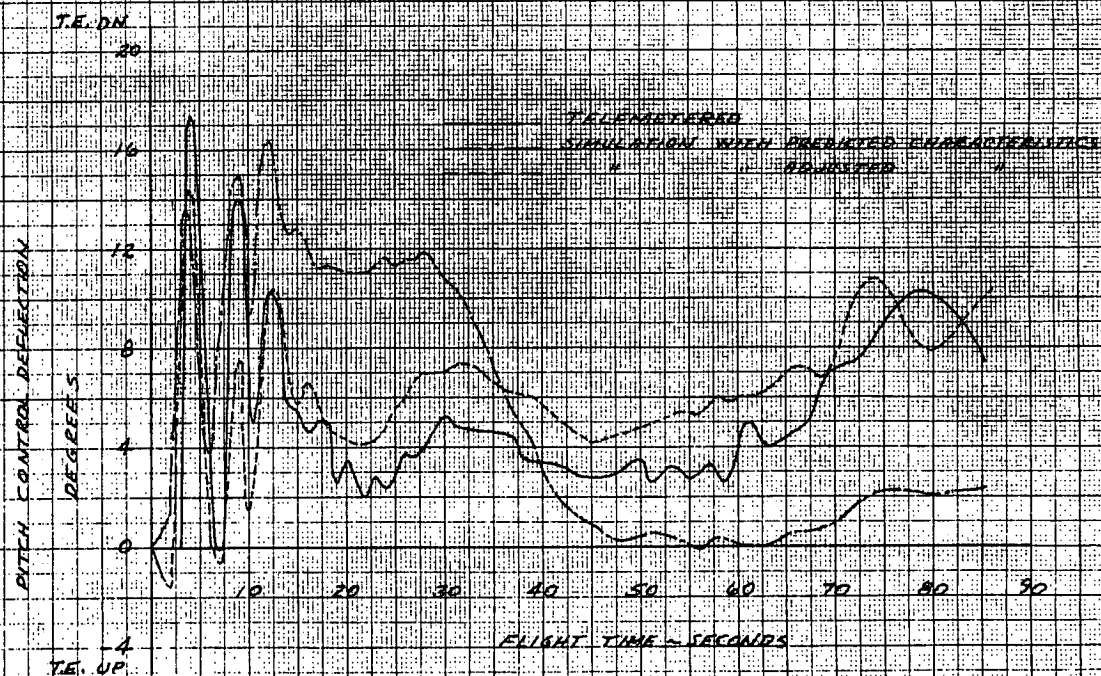
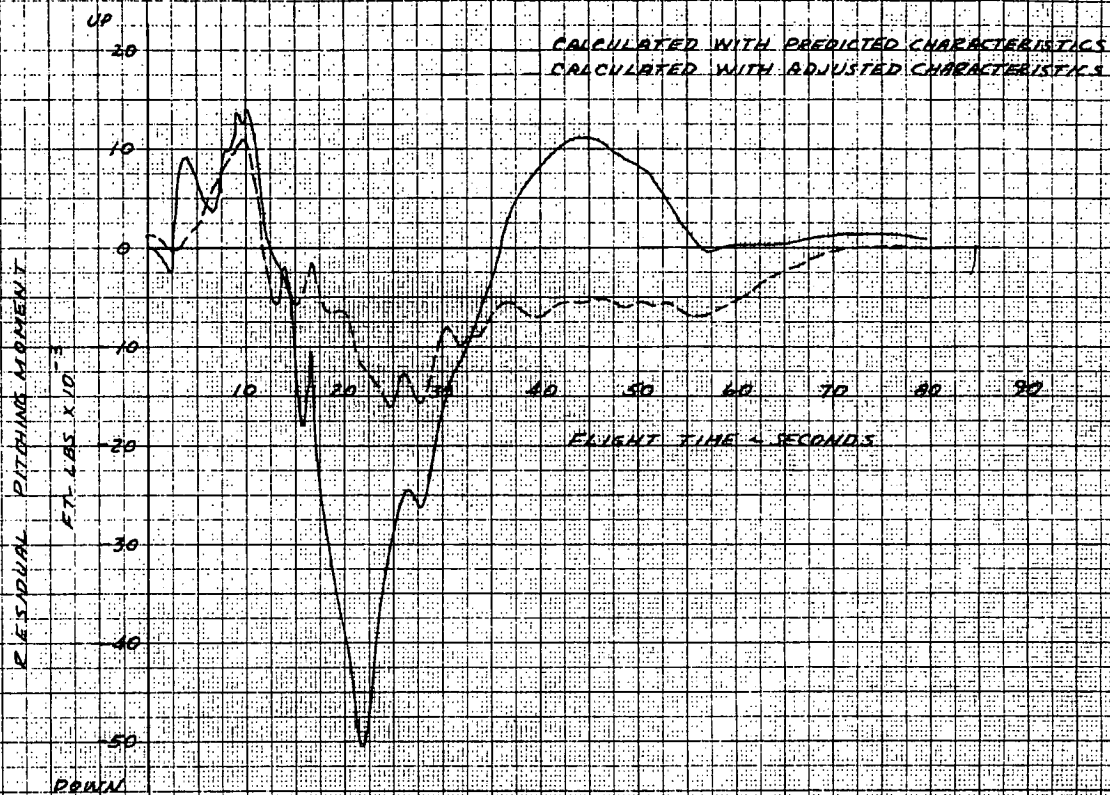


FIGURE 3.6  
S-137 FLIGHT DATA COMPARISON CONT'D

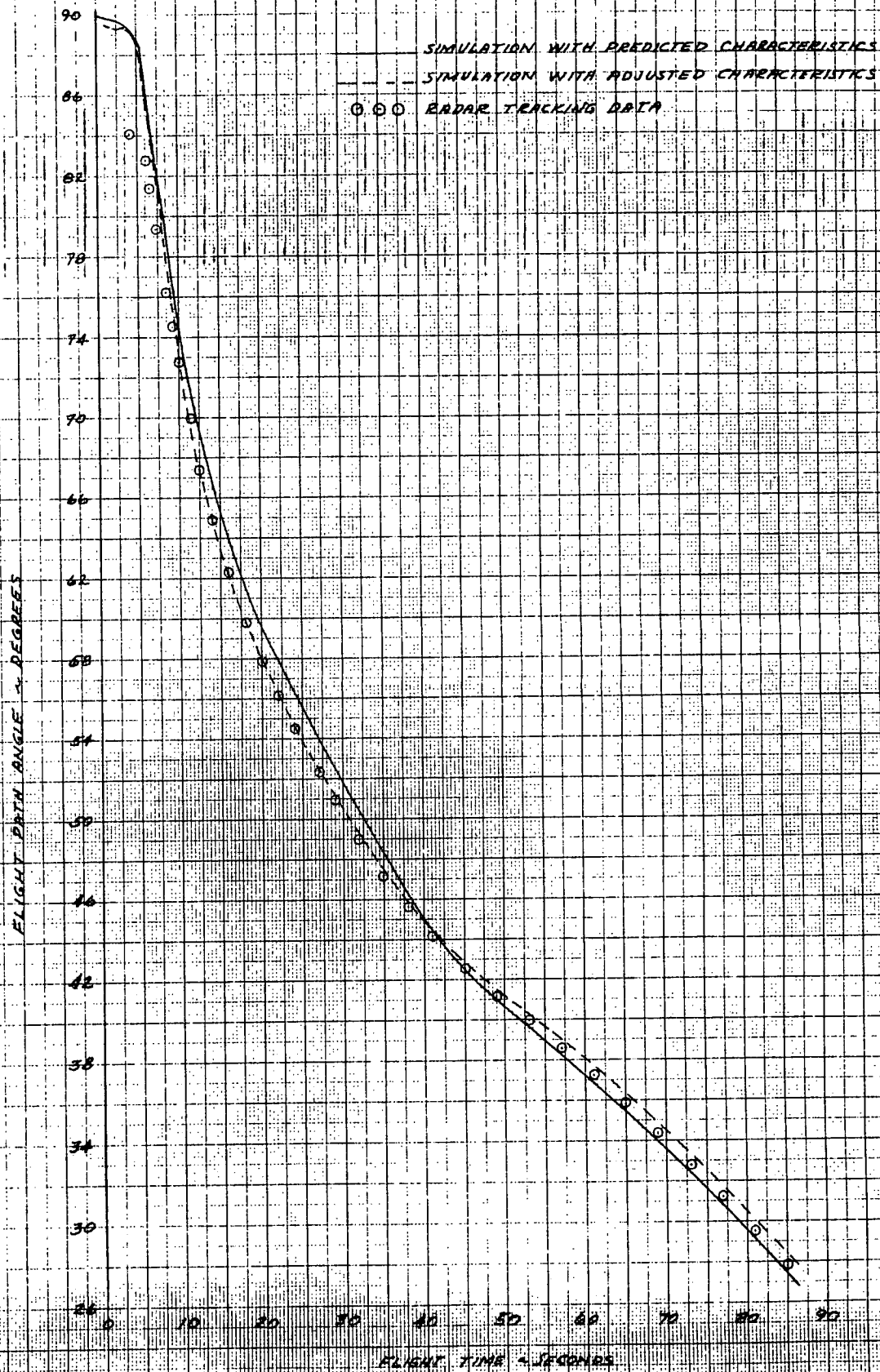


FIGURE 3C  
S-187 FLIGHT DATA COMPARISON CONT'D

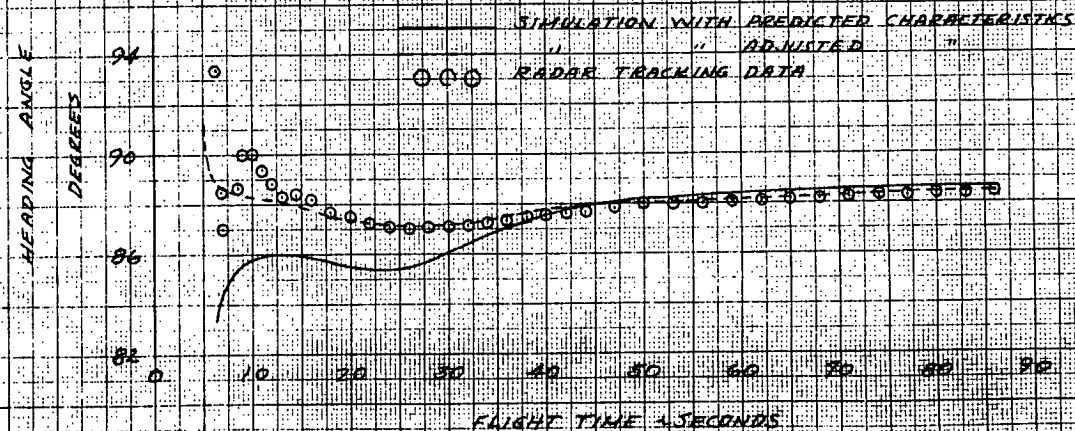
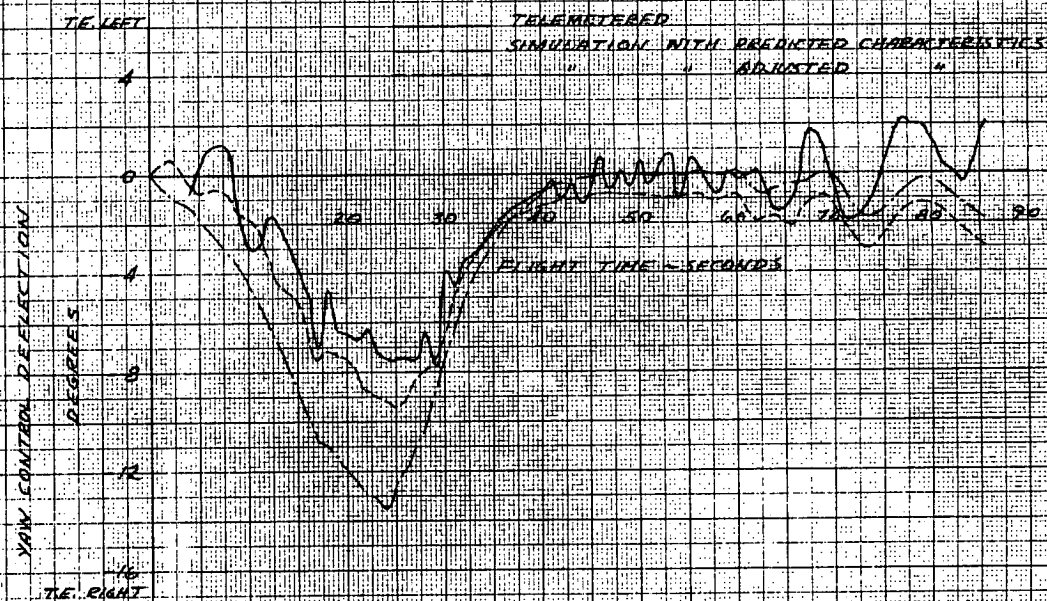
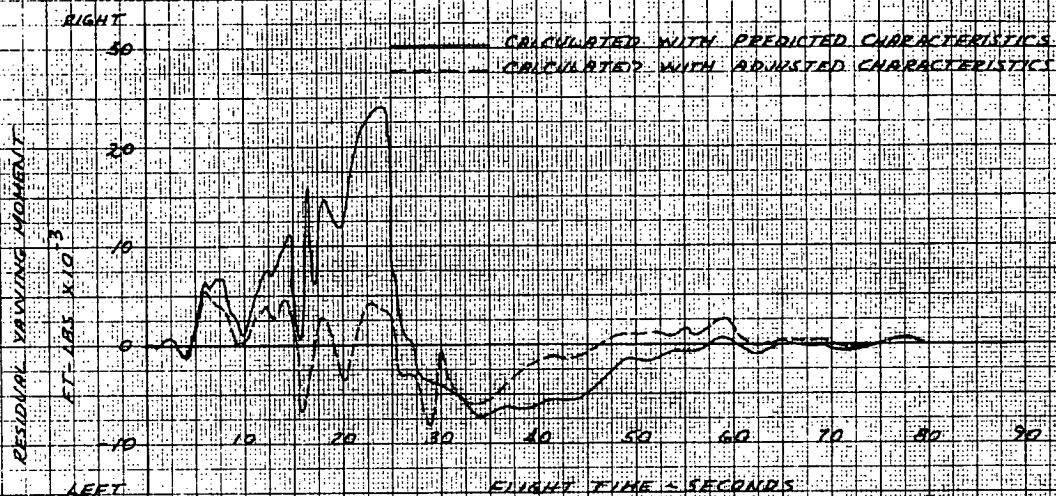


FIGURE 4A  
 S-141 FLIGHT DATA COMPARISON

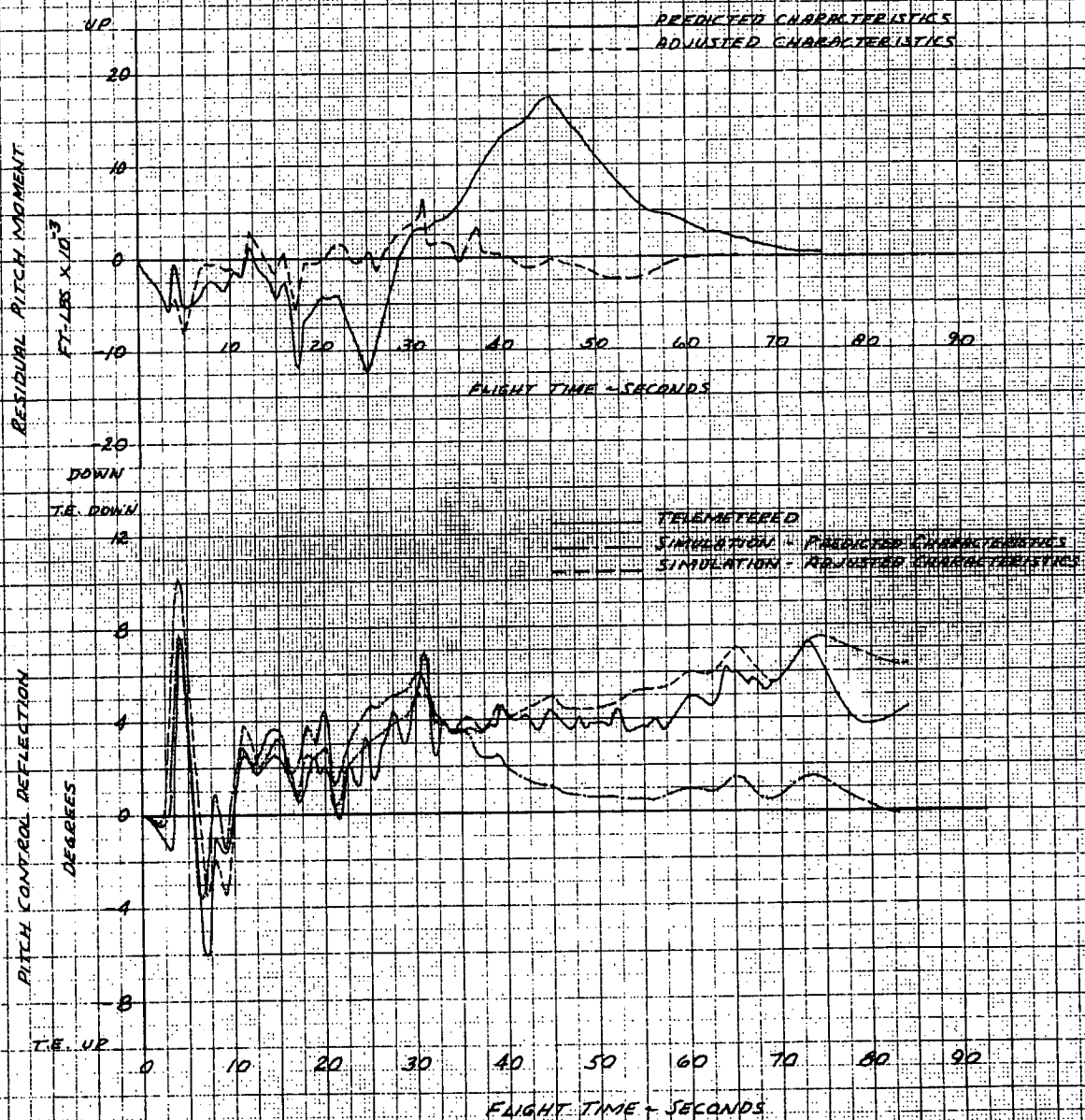




FIGURE 4.6  
5-1A1 FLIGHT DATA COMPARISON CONT'D

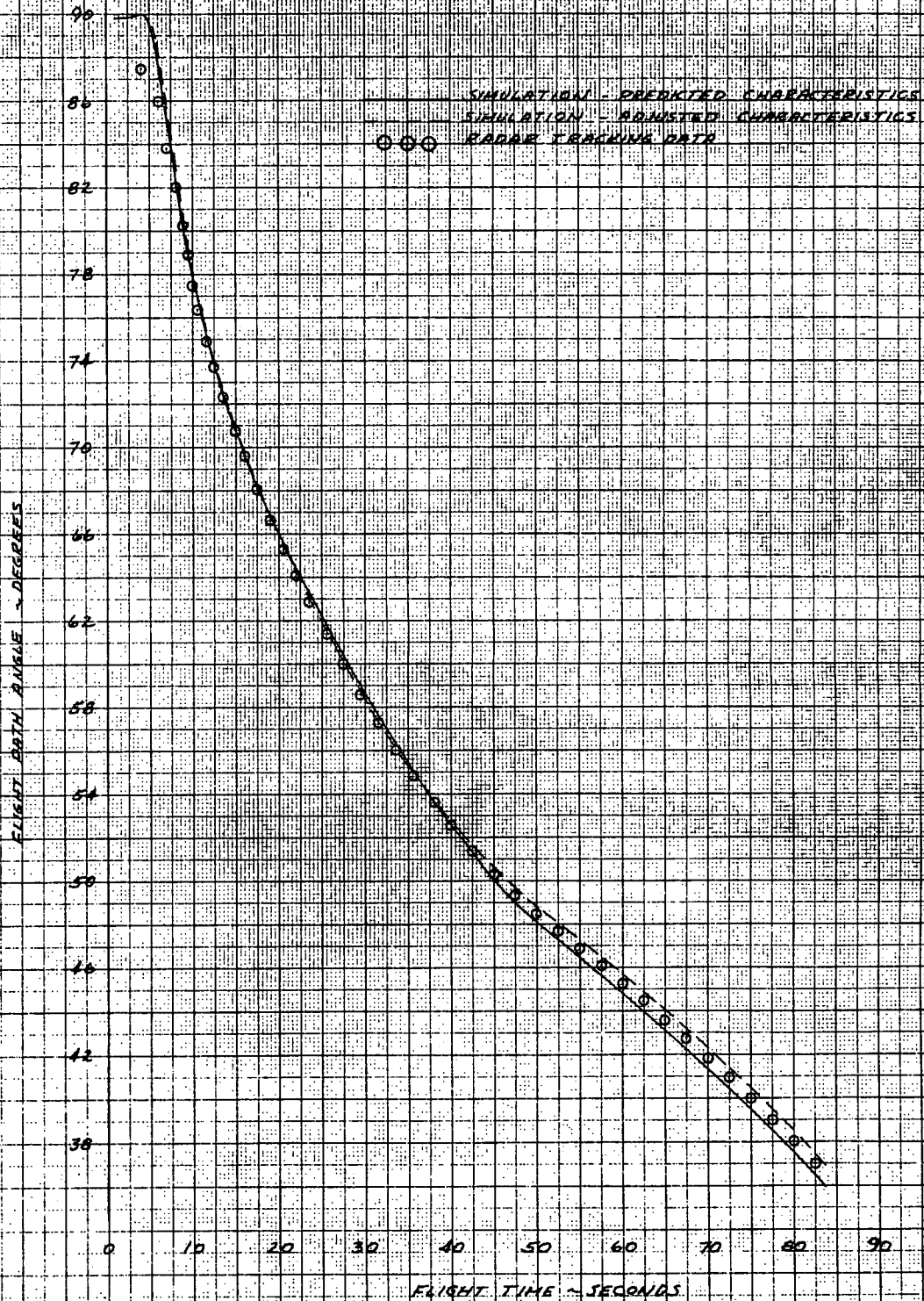


FIGURE 4C

S-141 FLIGHT DATA COMPARISON CONT'D

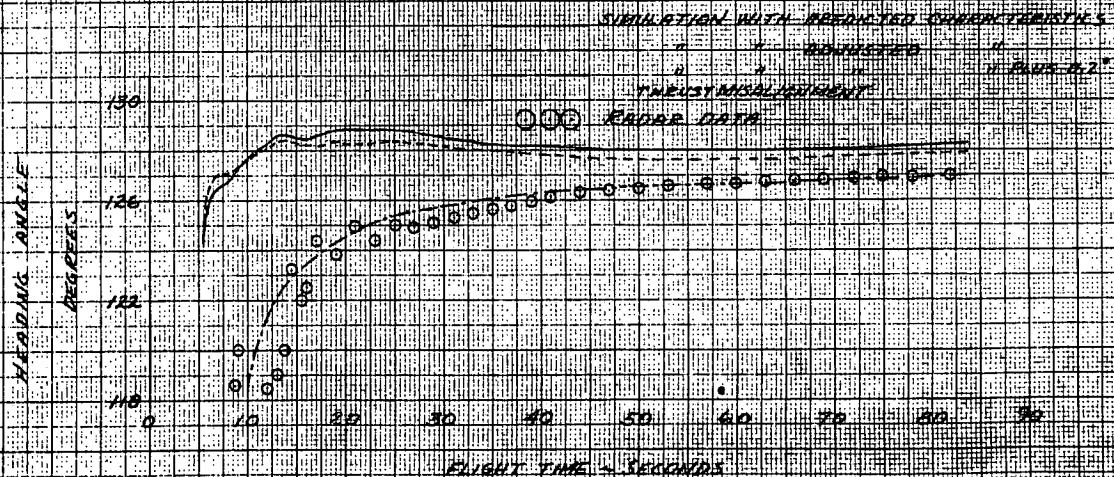
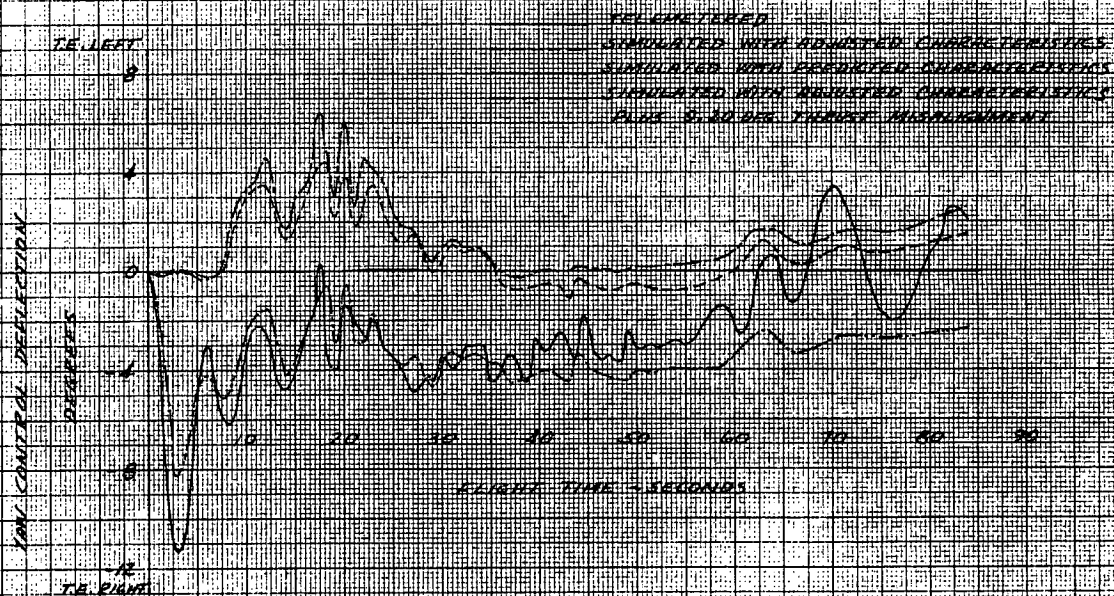
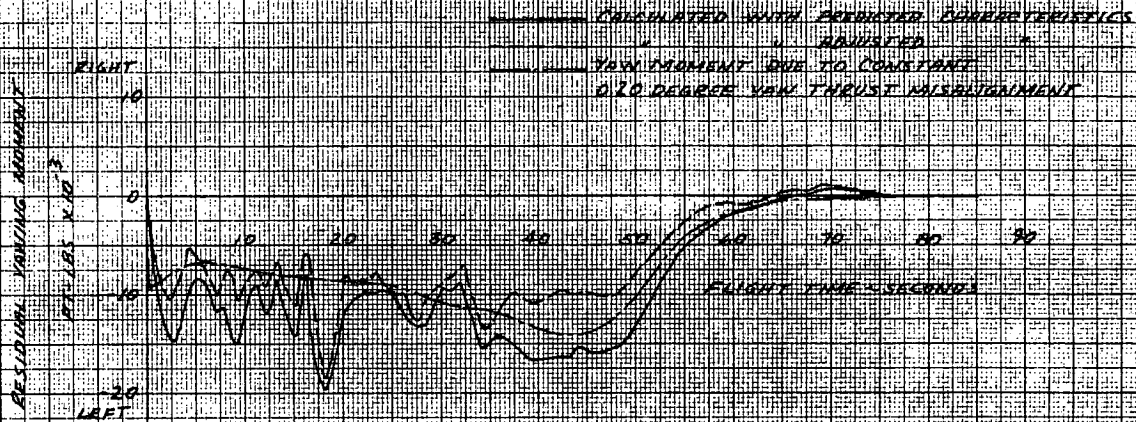


FIGURE 5a  
5-147 FLIGHT DATA COMPARISON

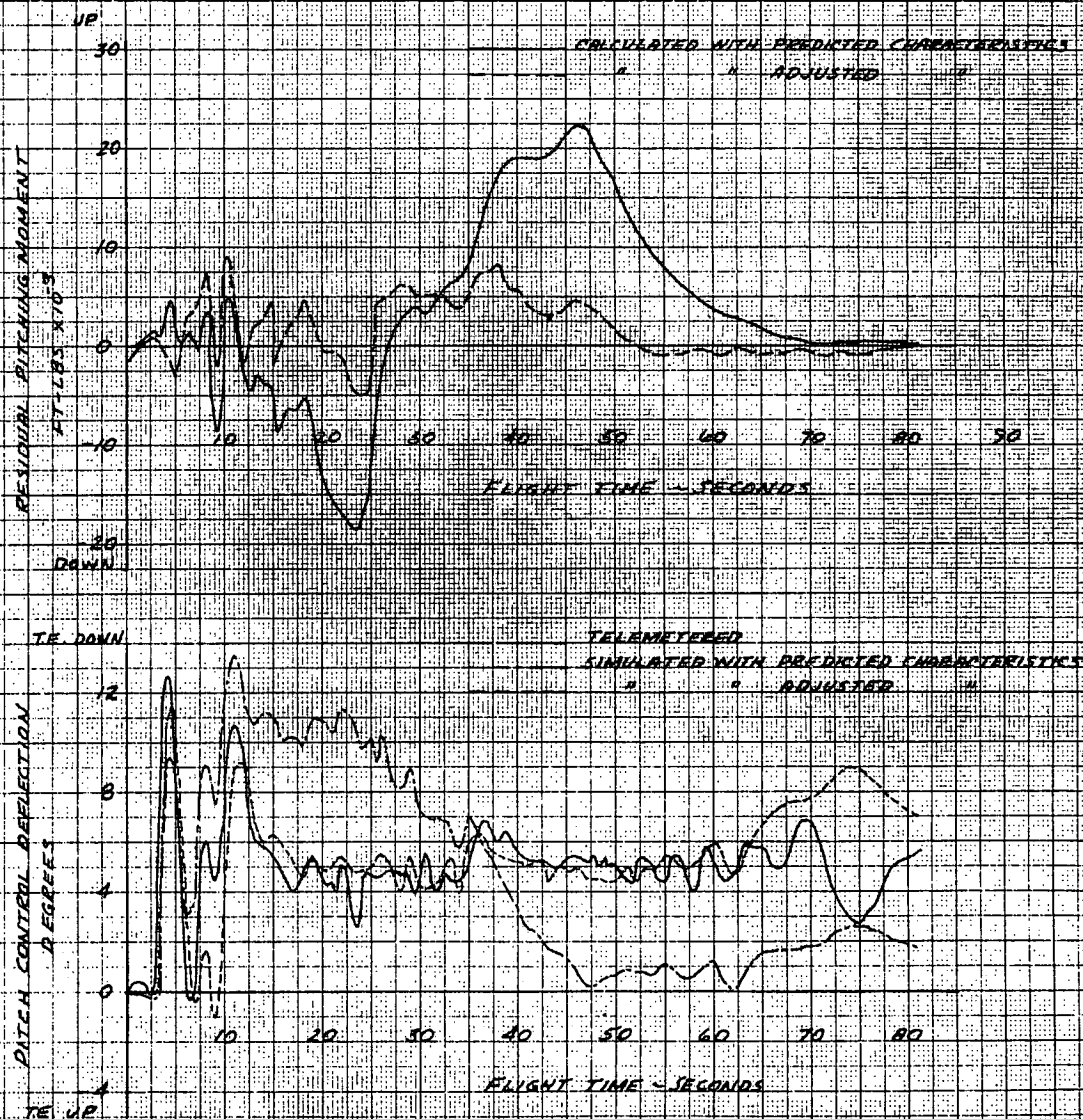




FIGURE 5b  
S-147 FLIGHT DATA COMPARISON CONT'D

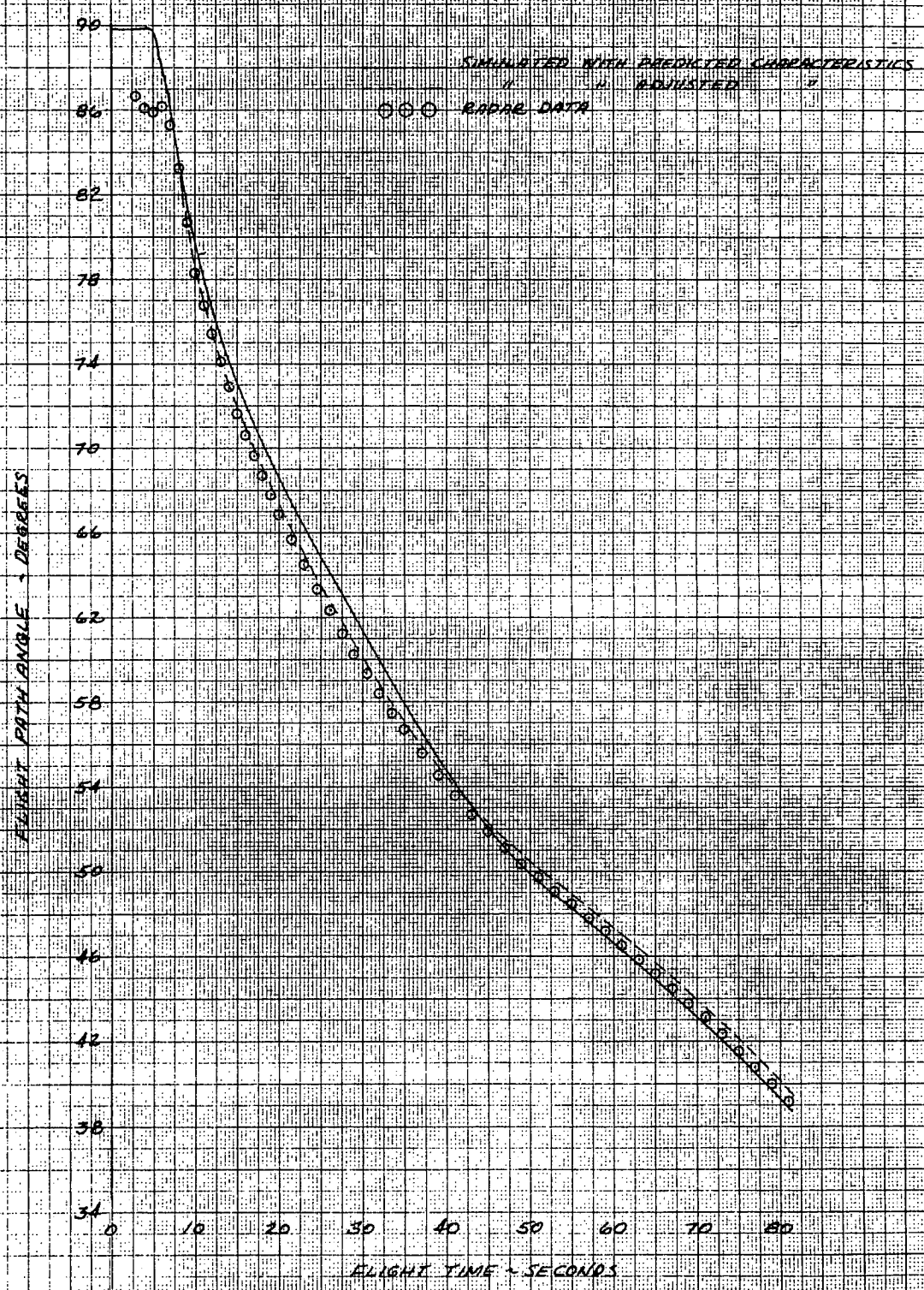




FIGURE 5C  
5-117 FLIGHT DATA COMPARISON CONT'D

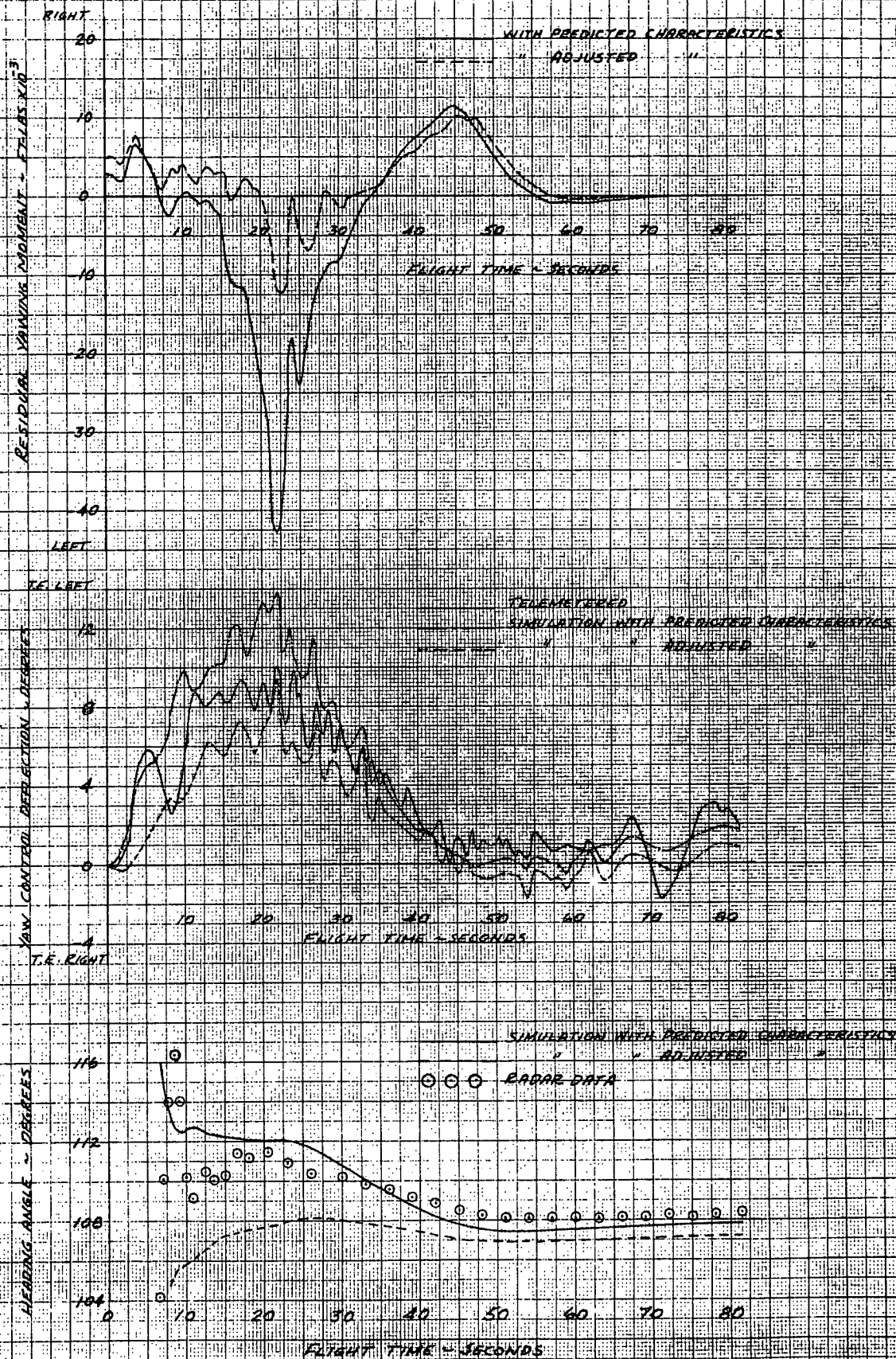


FIGURE 62  
 S-128 FLIGHT DATA COMPARISON

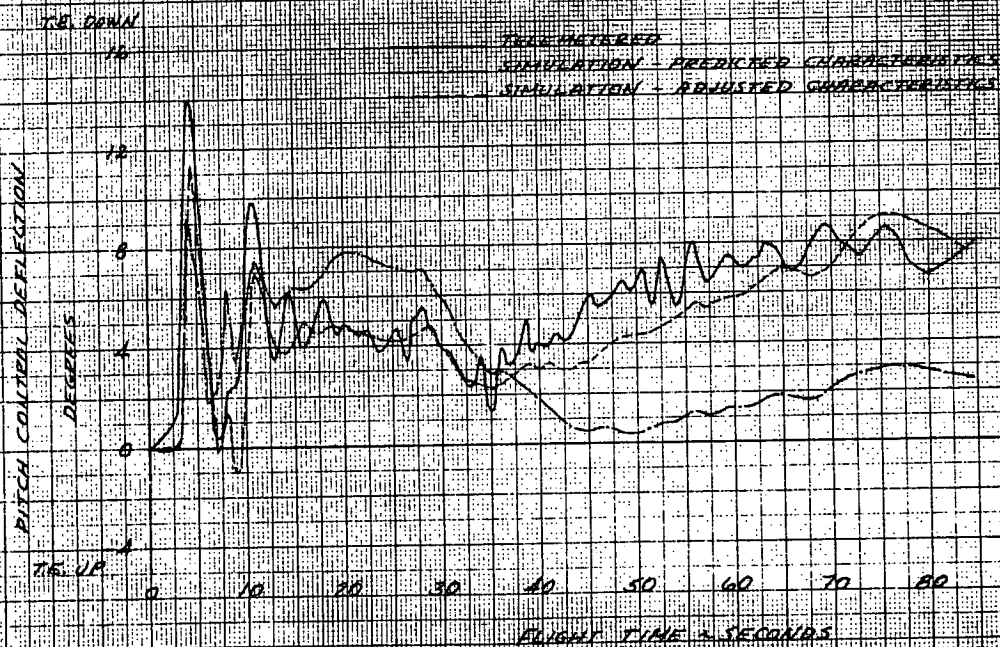
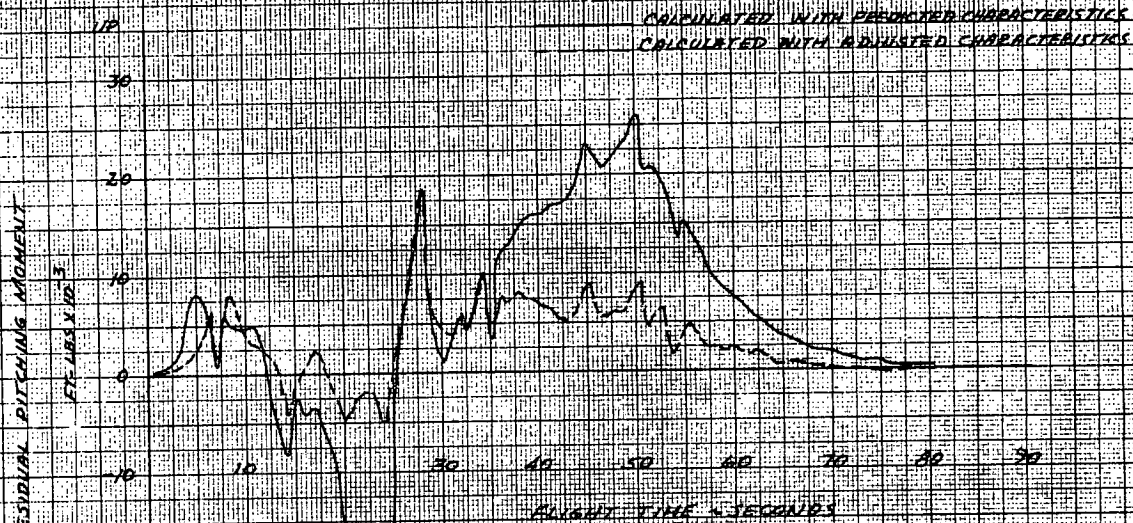


FIGURE 6.6  
 F-14A FLIGHT DATA COMPARISON CONT'D

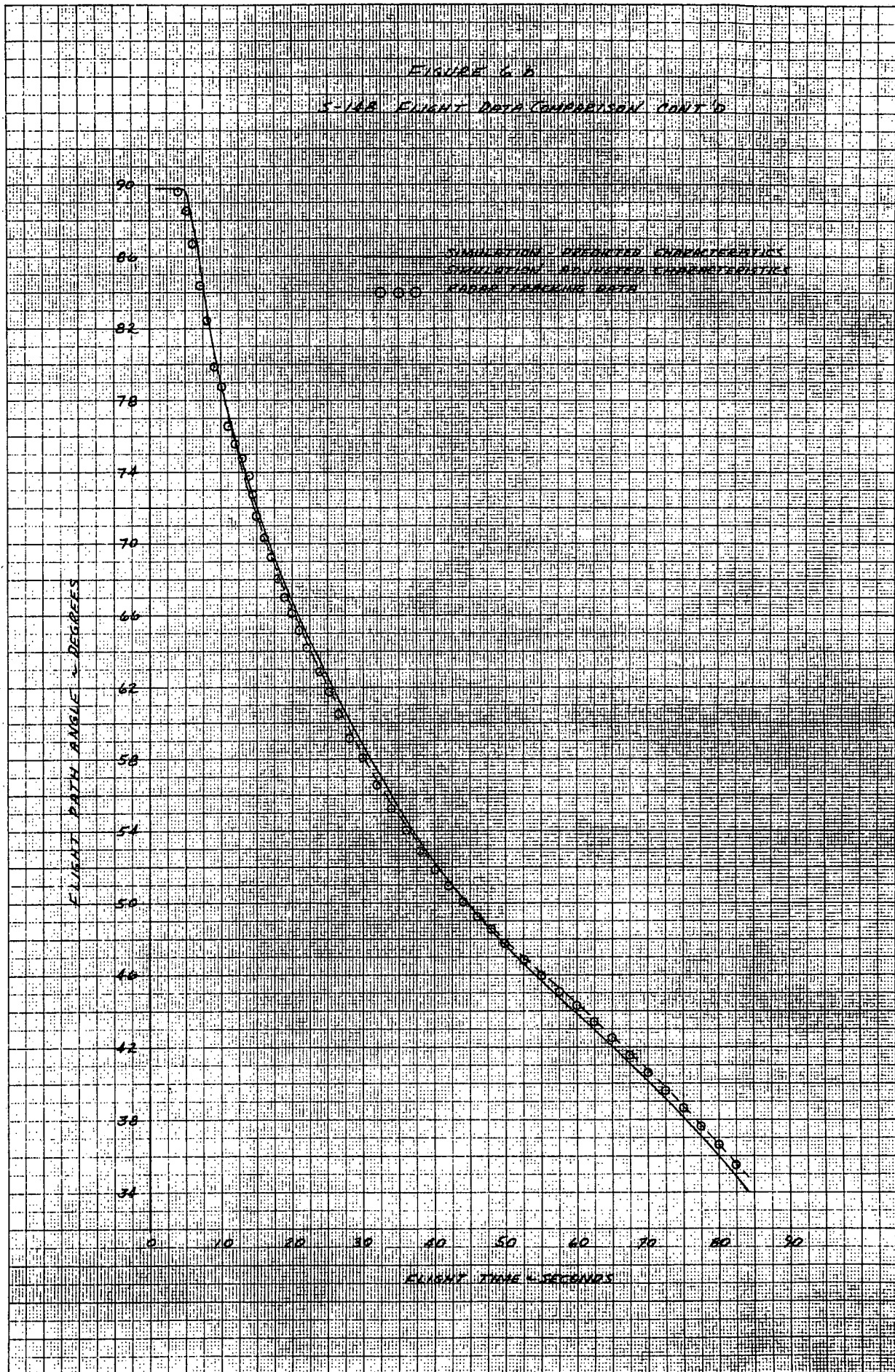




FIGURE 6C  
S-14B FLIGHT DATA COMPARISON CONT'D

The figure consists of three vertically stacked plots sharing a common x-axis representing Flight Time in seconds, ranging from 0 to 80.

**Top Plot: Residual Yawing Moment**  
Y-axis: RESIDUAL YAWING MOMENT, FT-LBS  $\times 10^{-3}$ , ranging from -20 to 30.  
Legend:  
- CALCULATED WITH PREDICTED CHARACTERISTICS (solid line)  
- CALCULATED WITH ADJUSTED CHARACTERISTICS (dashed line)  
The plot shows significant oscillations, with a major peak around 25 seconds reaching approximately 25  $\times 10^3$  FT-LBS.

**Middle Plot: Yaw Control Deflection**  
Y-axis: YAW CONTROL DEFLECTION, DEGREES, ranging from -8 to 4.  
Legend:  
- TELEMETERED (solid line with dots)  
- SIMULATION - PREDICTED CHARACTERISTICS (solid line)  
- SIMULATION - ADJUSTED CHARACTERISTICS (dashed line)  
The plot shows fluctuations between -4 and 4 degrees, with the adjusted simulation closely following the telemetered data.

**Bottom Plot: Heading Angle**  
Y-axis: HEADING ANGLE, DEGREES, ranging from 148 to 180.  
Legend:  
- SIMULATION - PREDICTED CHARACTERISTICS (solid line)  
- SIMULATION - ADJUSTED CHARACTERISTICS (dashed line)  
- RADAR TRACING DATA (circles)  
The plot shows the heading angle starting near 180 degrees and settling around 172 degrees after 20 seconds. The adjusted simulation closely matches the radar tracing data.

FIGURE 7a.  
S-129 FLIGHT DATA COMPARISON

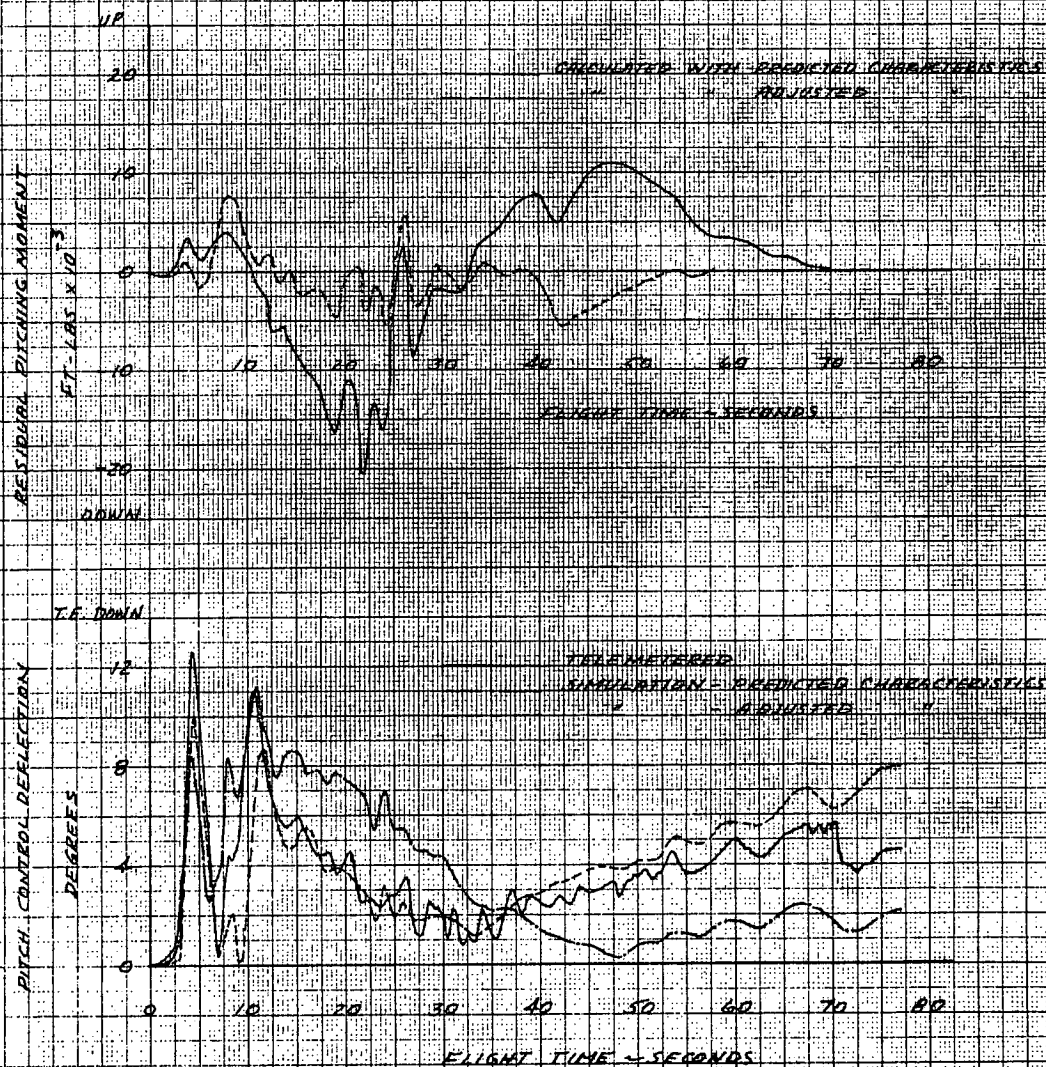


FIGURE 7b  
S-149 FLIGHT DATA COMPARISON/ CONT'D

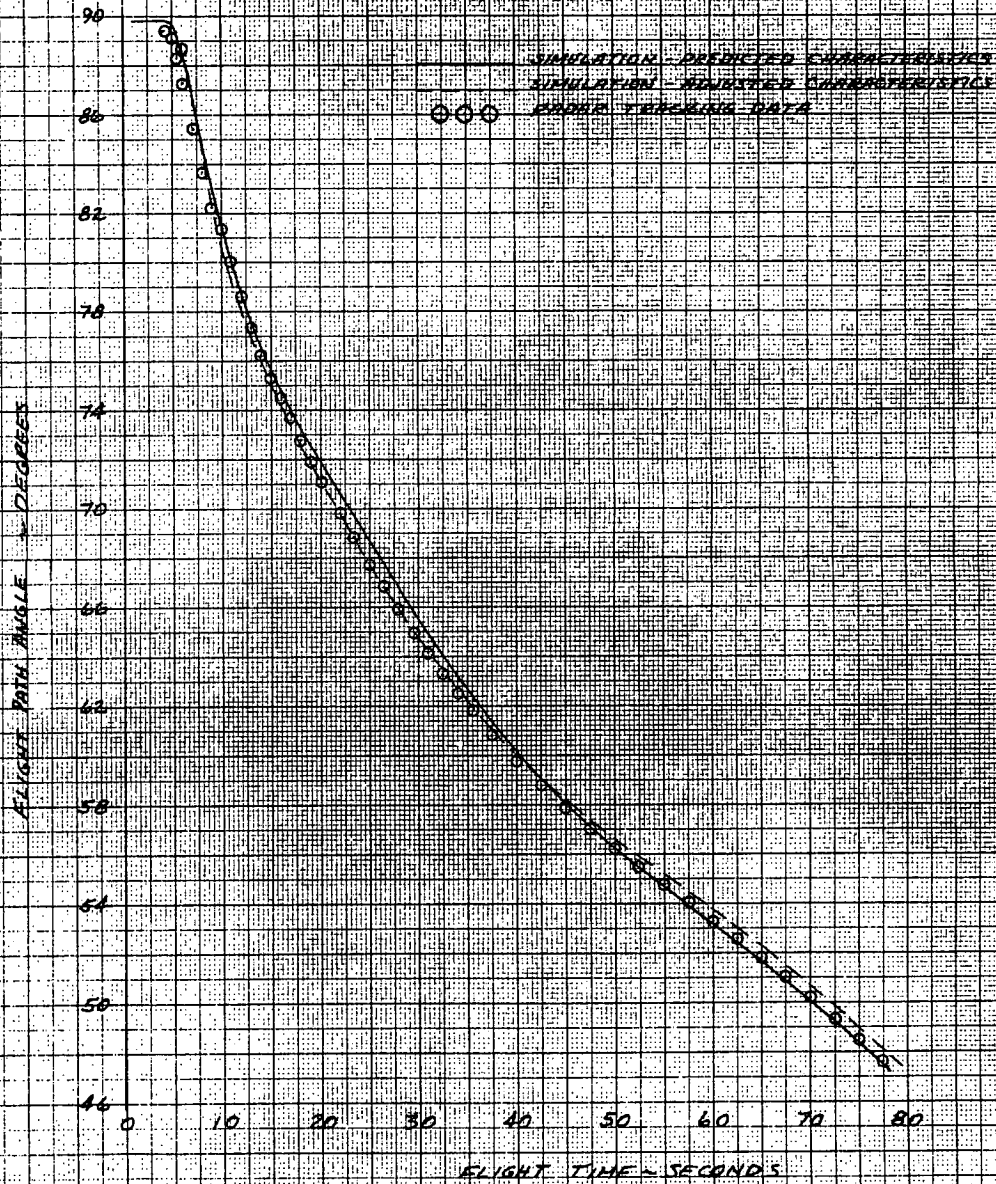




FIGURE 7C

S-149 FLIGHT DATA COMPARISONS CONT'D

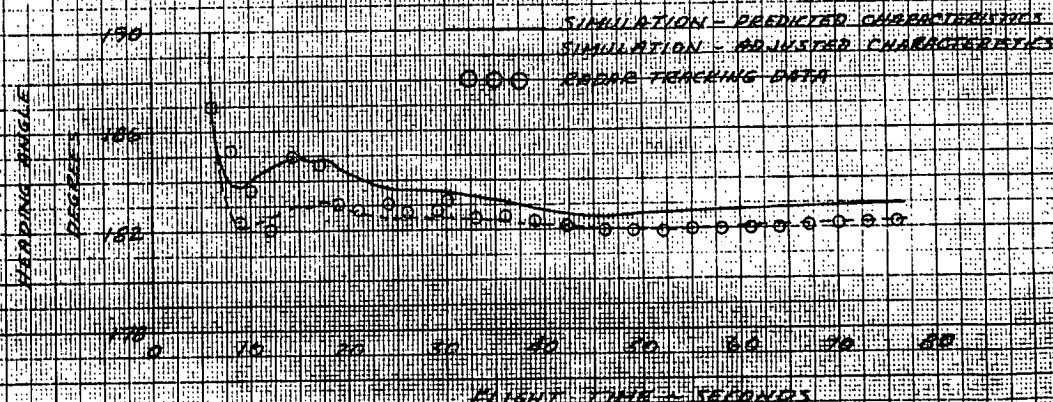
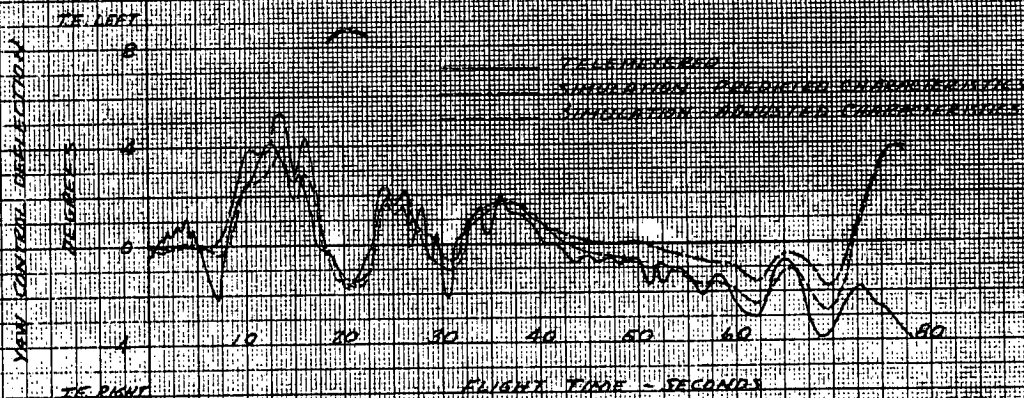
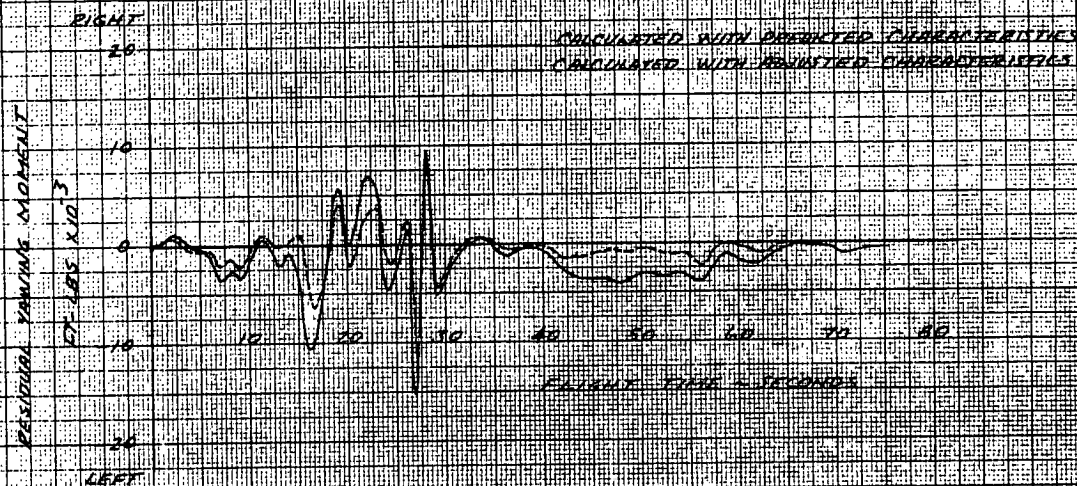


FIGURE B.2  
5-150 FLIGHT DATA COMPARISON

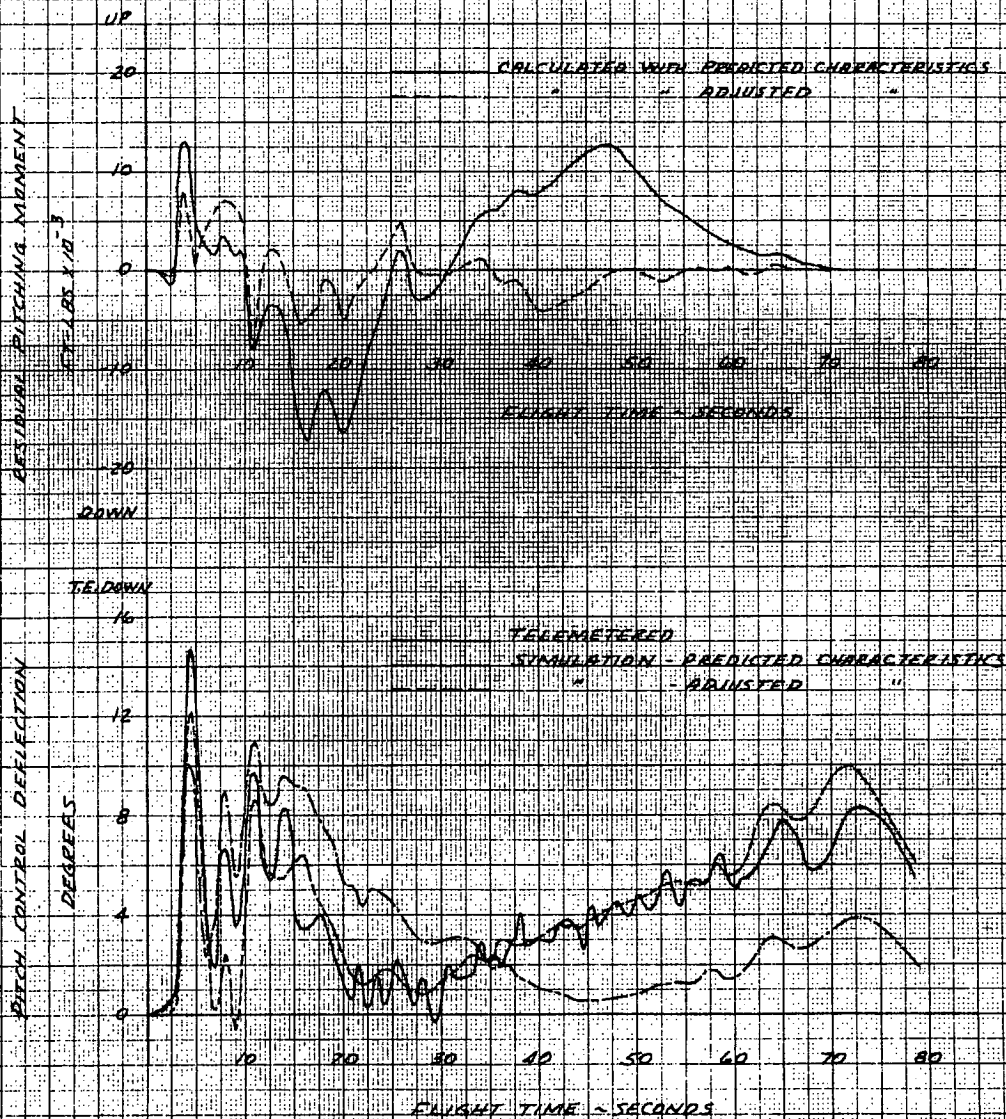




FIGURE 8.6  
 F-150 FLIGHT DATA COMPARISON CONT'D

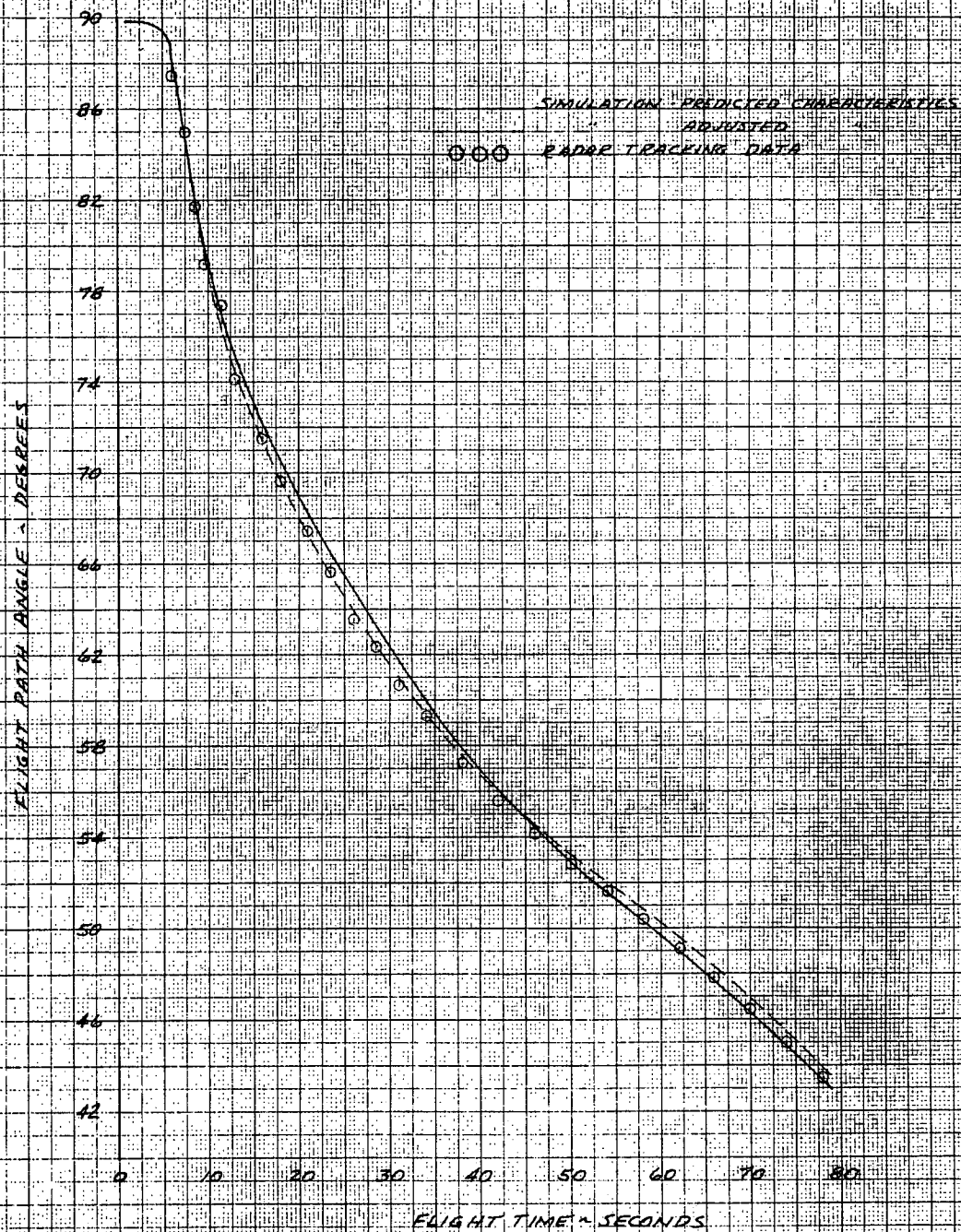


FIGURE 84  
 S-150 FLIGHT DATA COMPARISON CONT'D

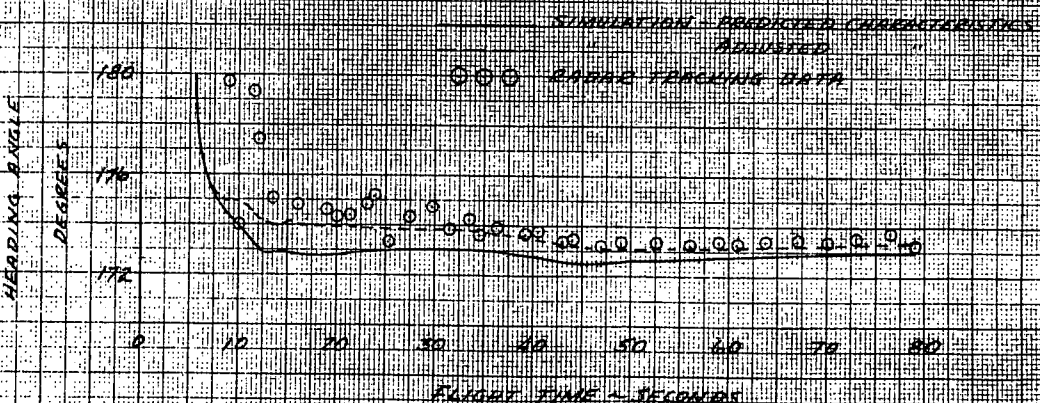
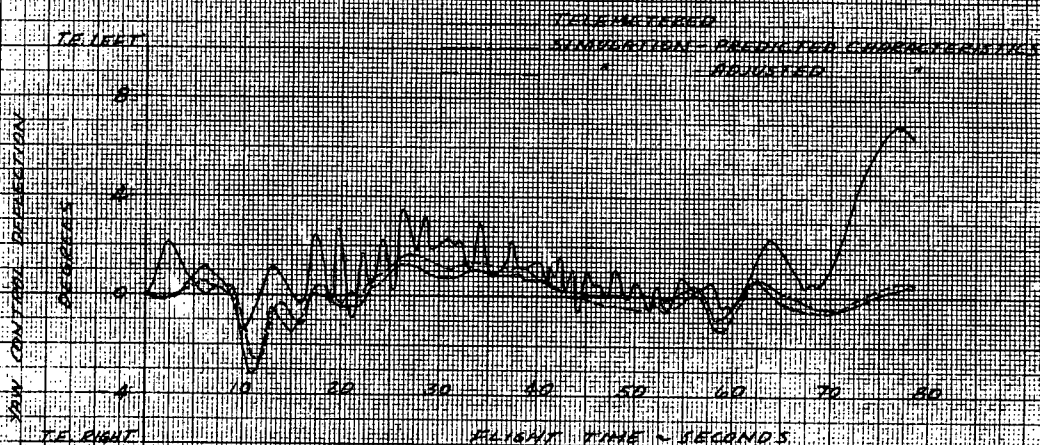
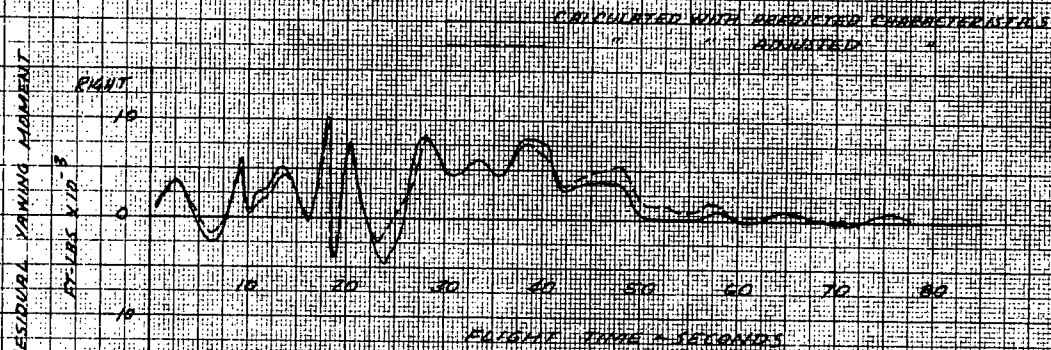


FIGURE 9a  
F-151 FLIGHT DATA COMPARISON

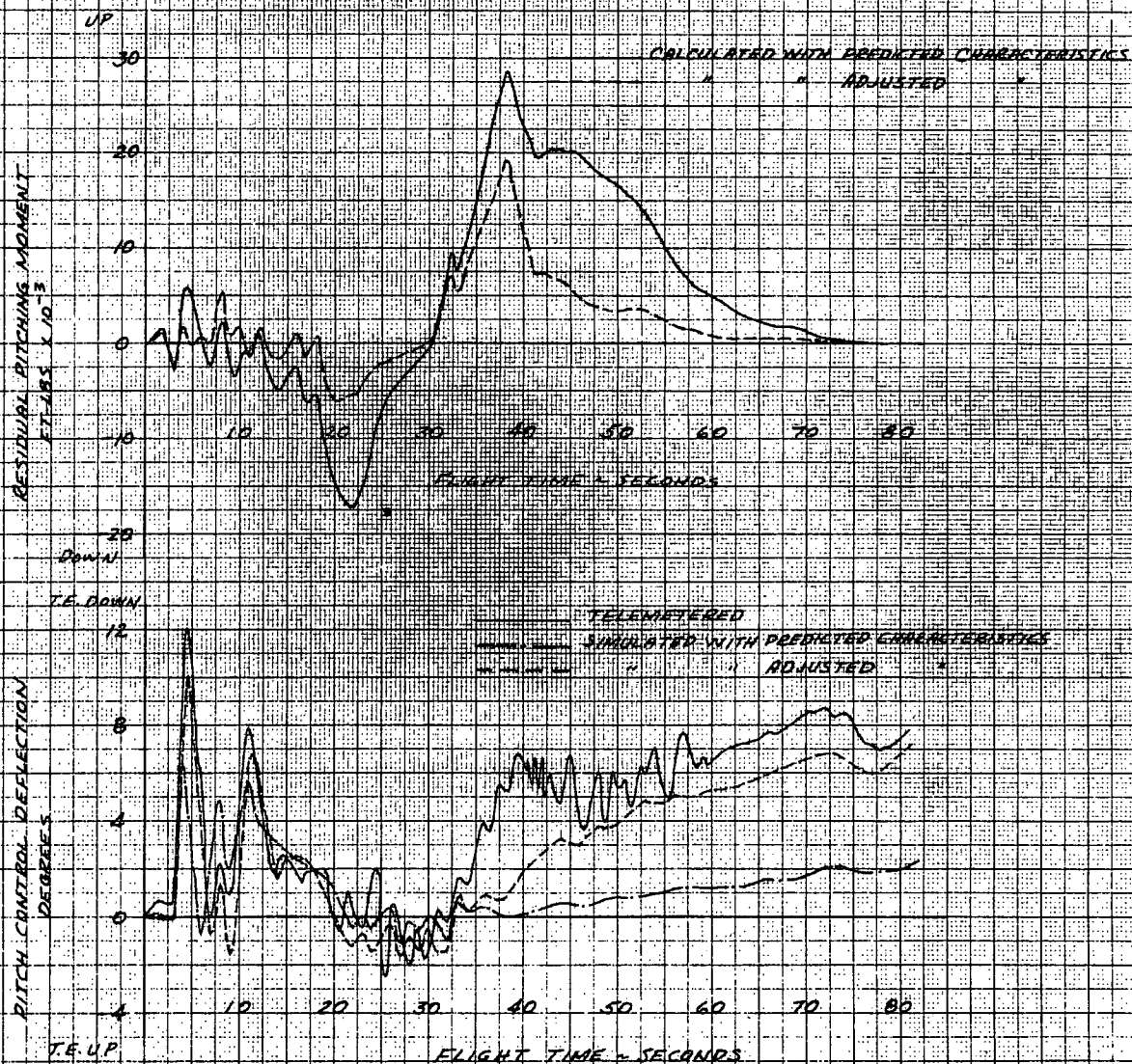




FIGURE 9b  
S-151 FLIGHT DATA COMPARISON CONTD

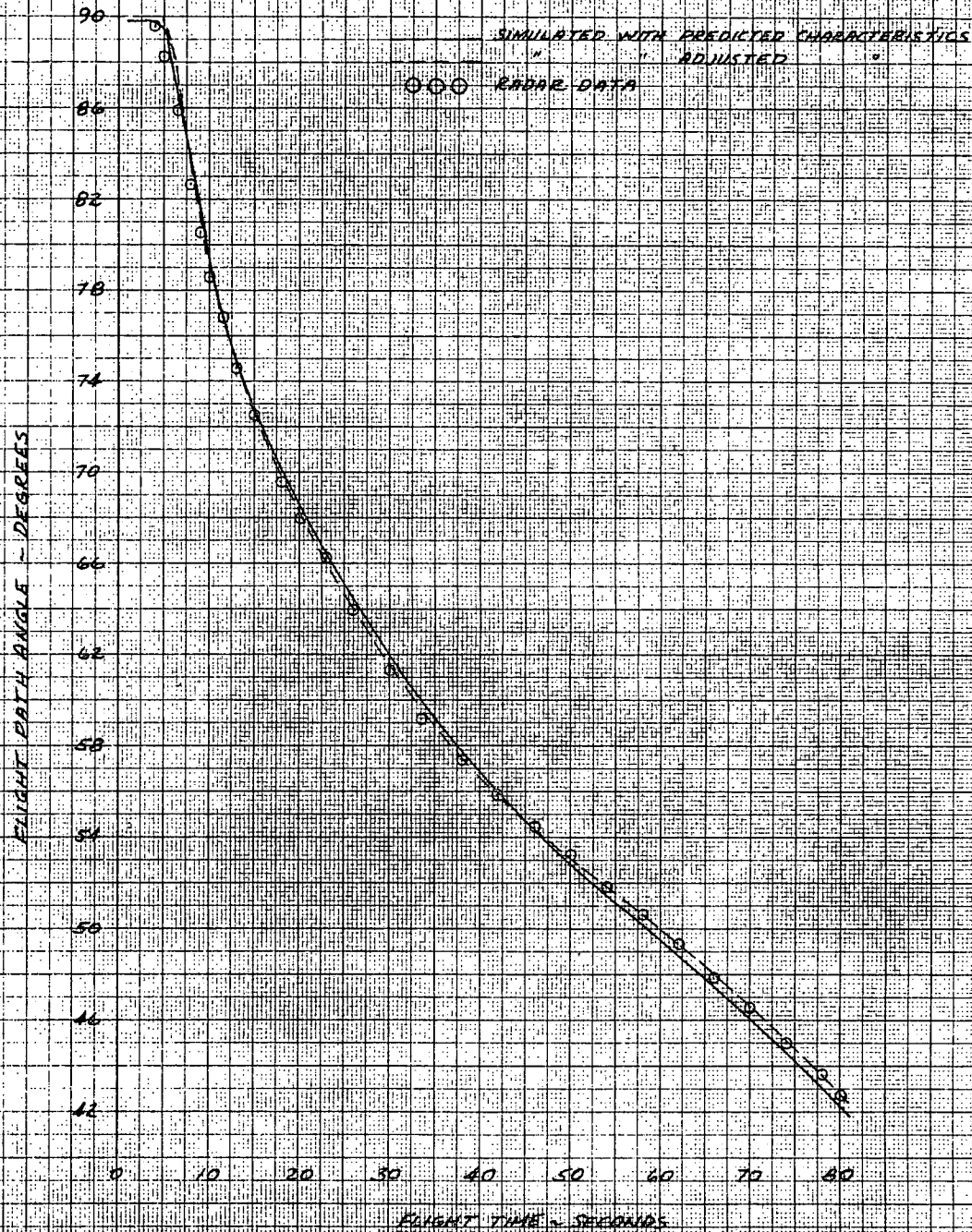


FIGURE 9C  
S-151 FLIGHT DATA COMPARISON CONT'D

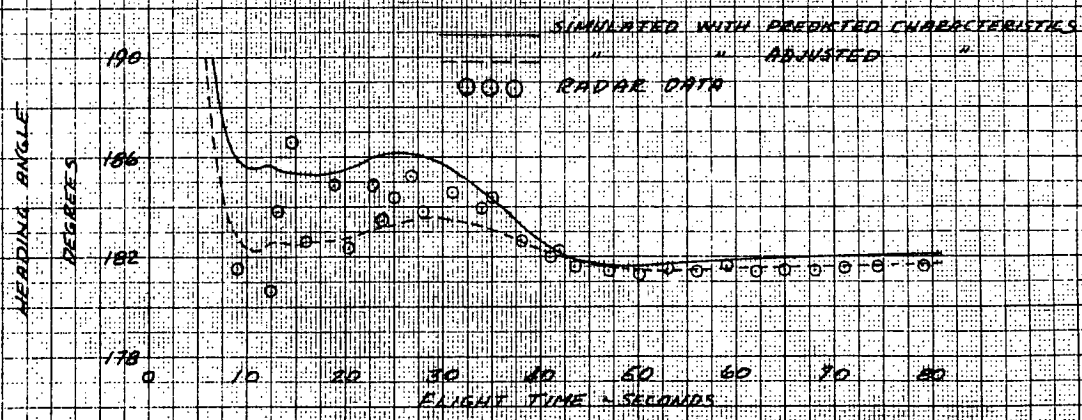
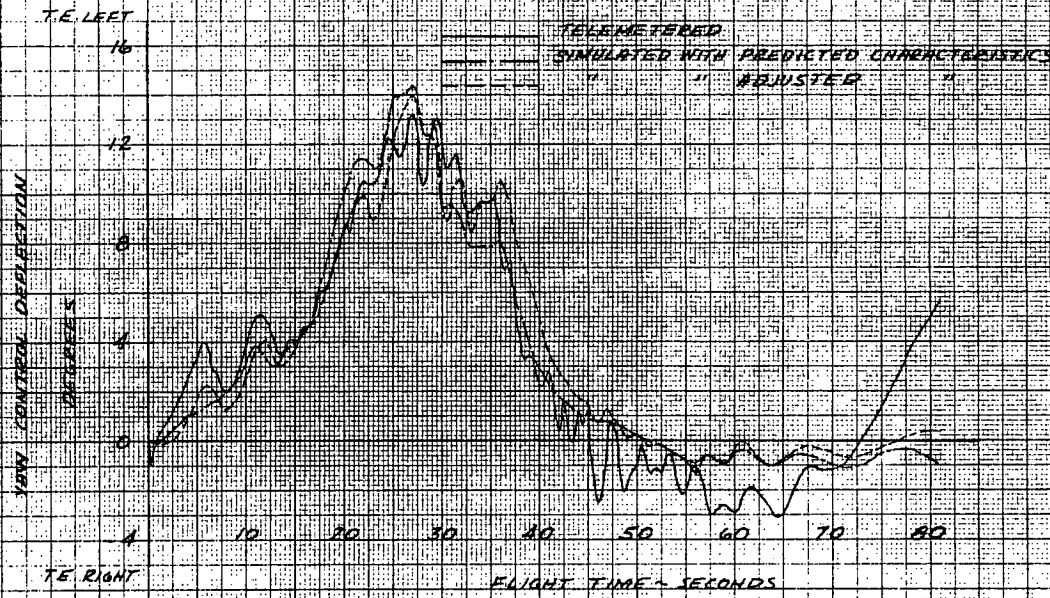
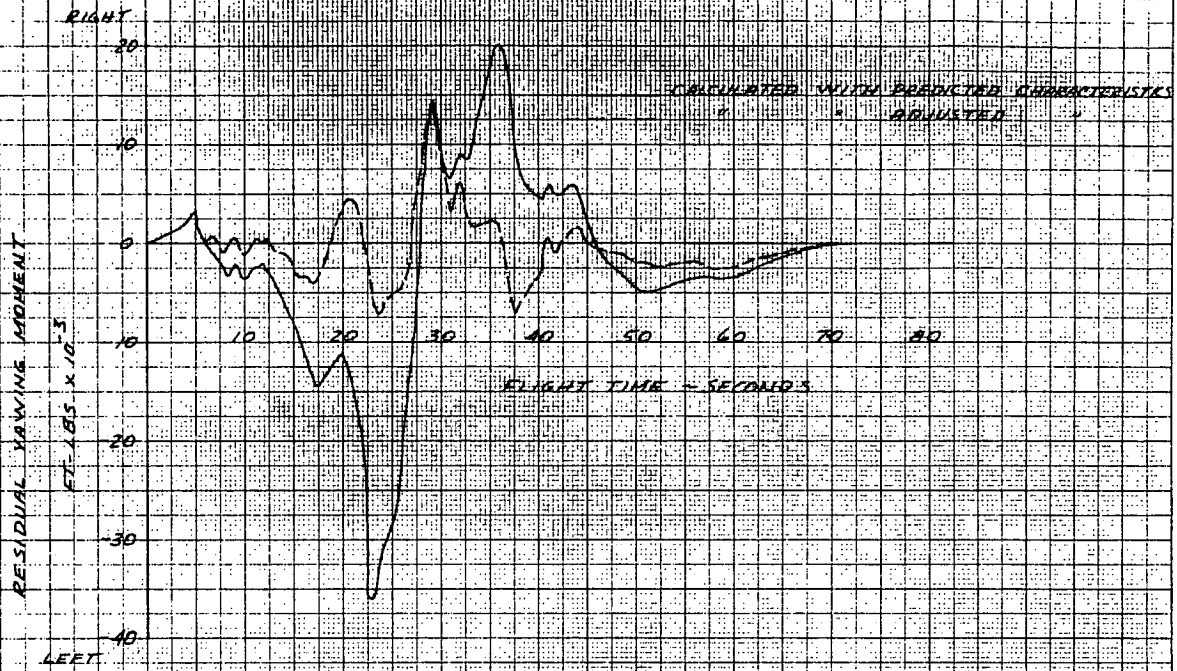


FIGURE 10a  
S-152 FLIGHT DATA COMPARISON

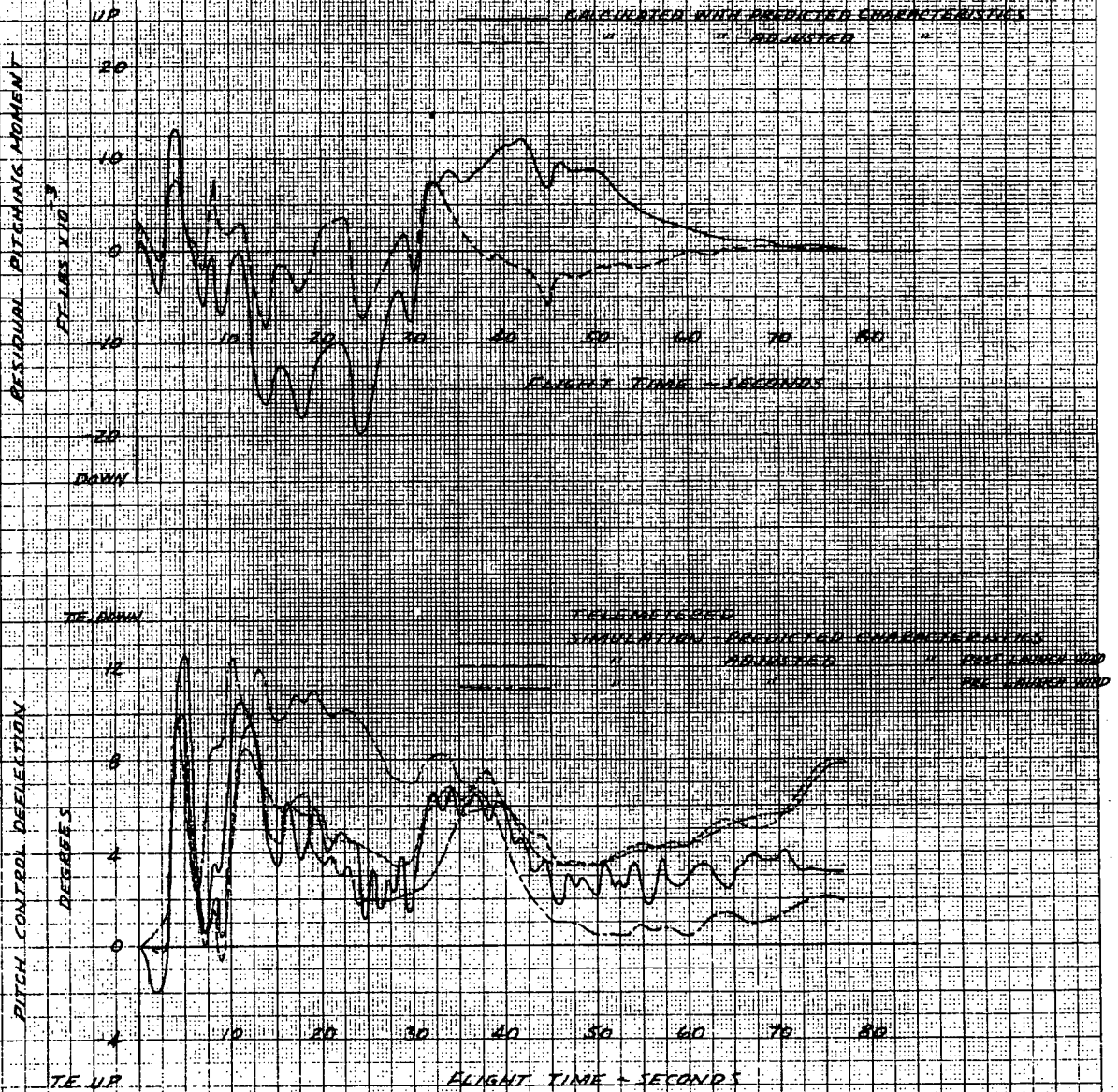




FIGURE 10.6  
S-152 FLIGHT DATA COMPARISON CONT'D

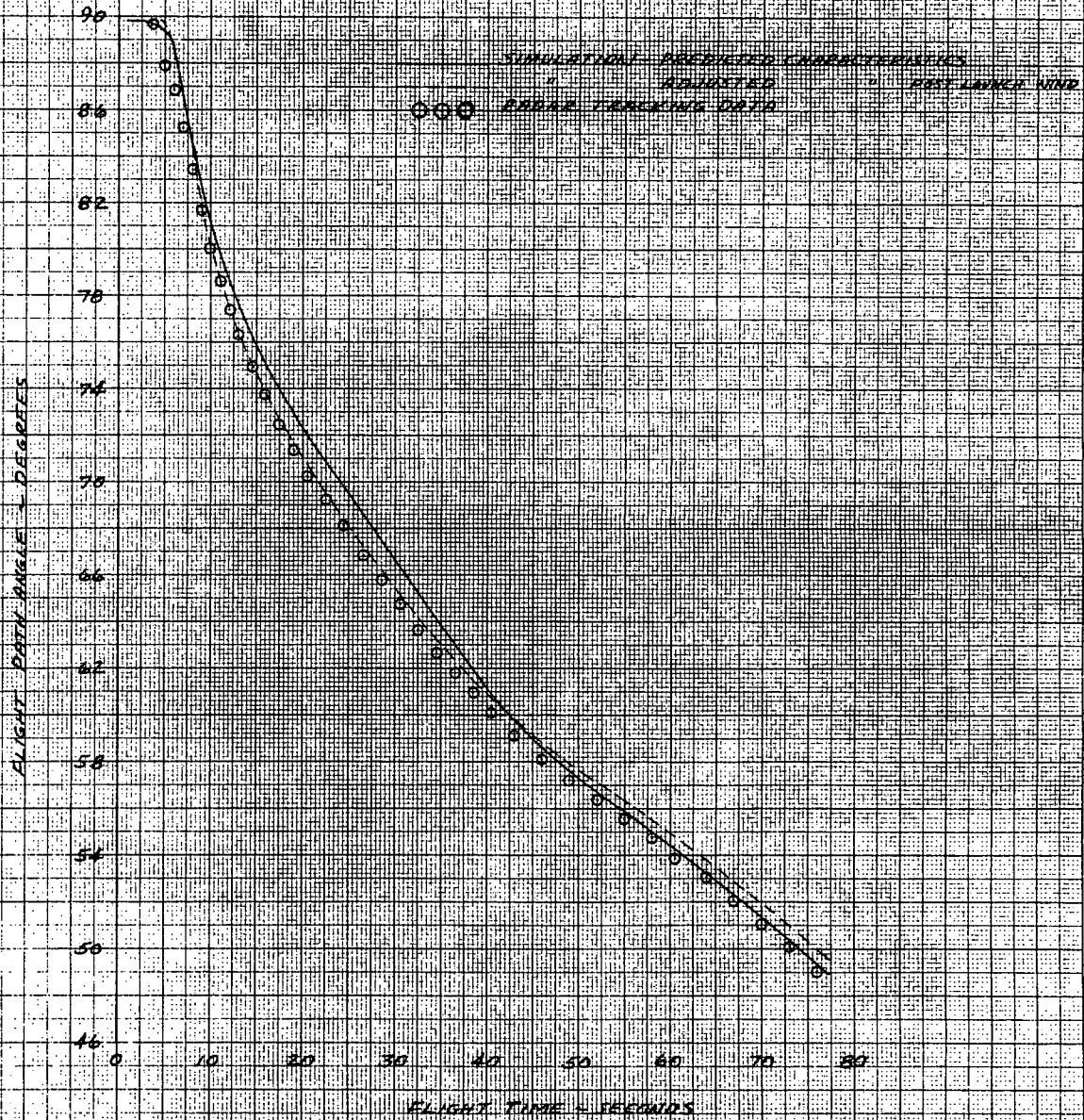




FIGURE 10C

5-152 FLIGHT DATA COMPARISON CONT'D

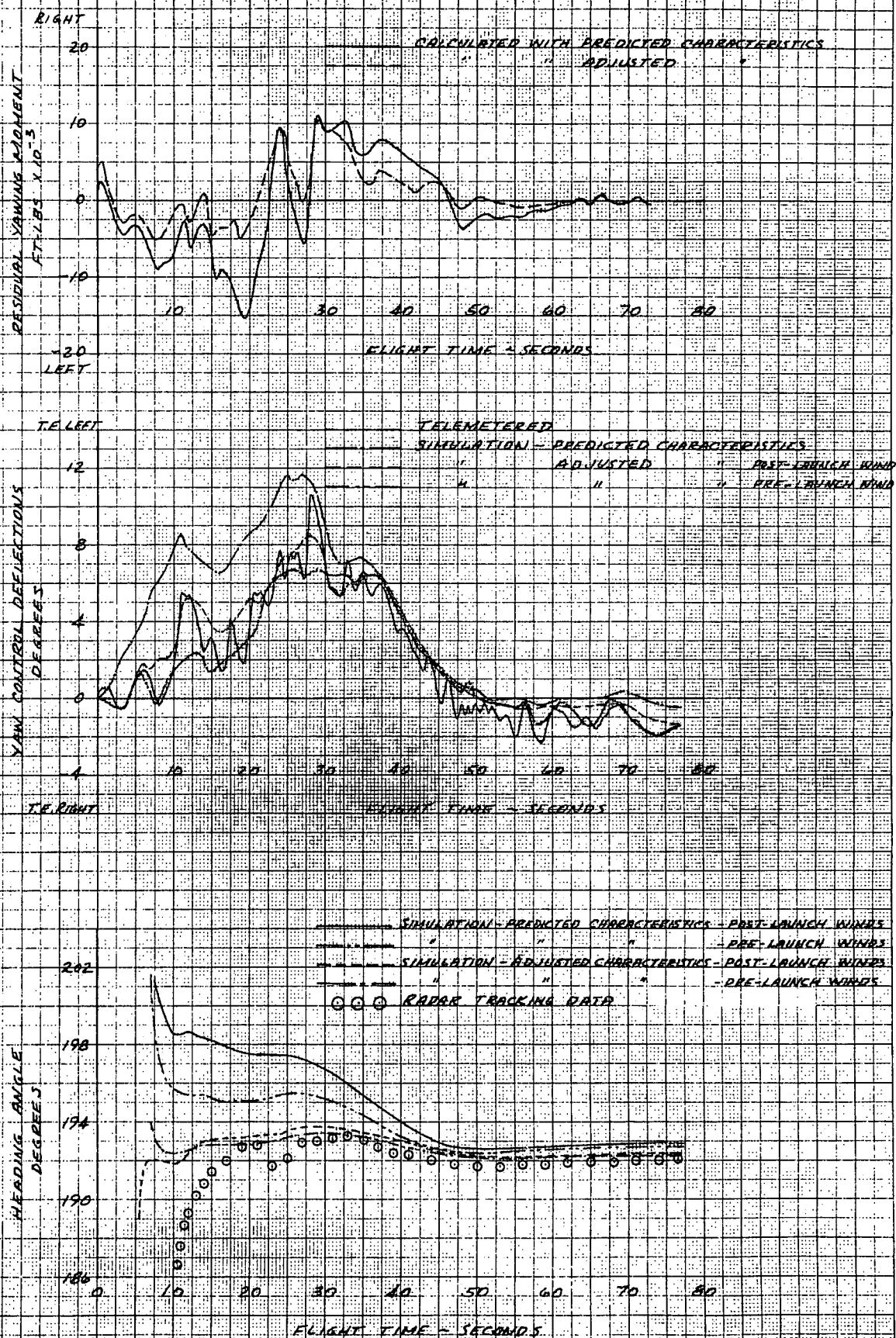


FIGURE 11a  
S-154 FLIGHT DATA COMPARISON

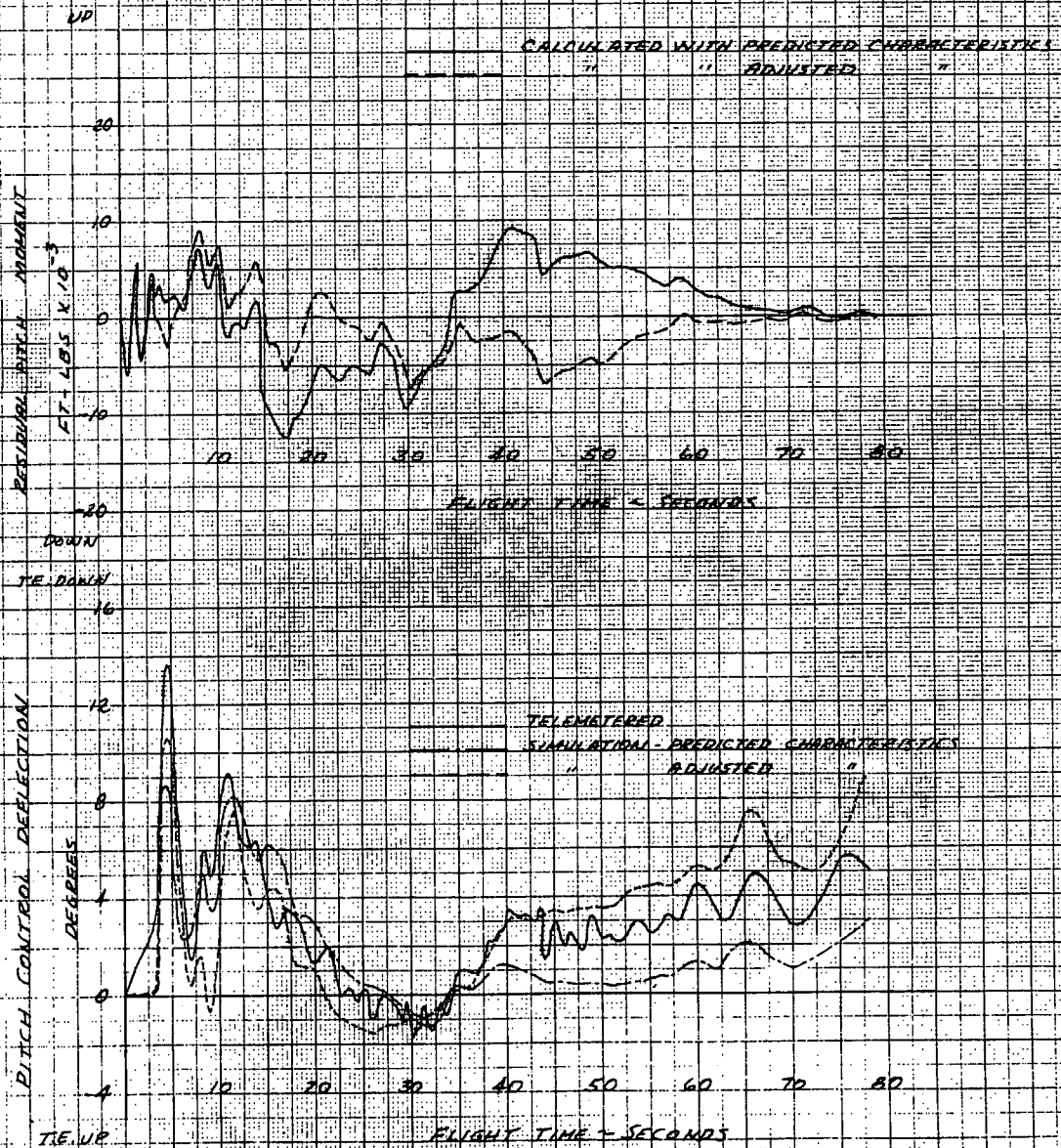


FIGURE 11b  
S-154 FLIGHT DATA COMPARISON CONT'D

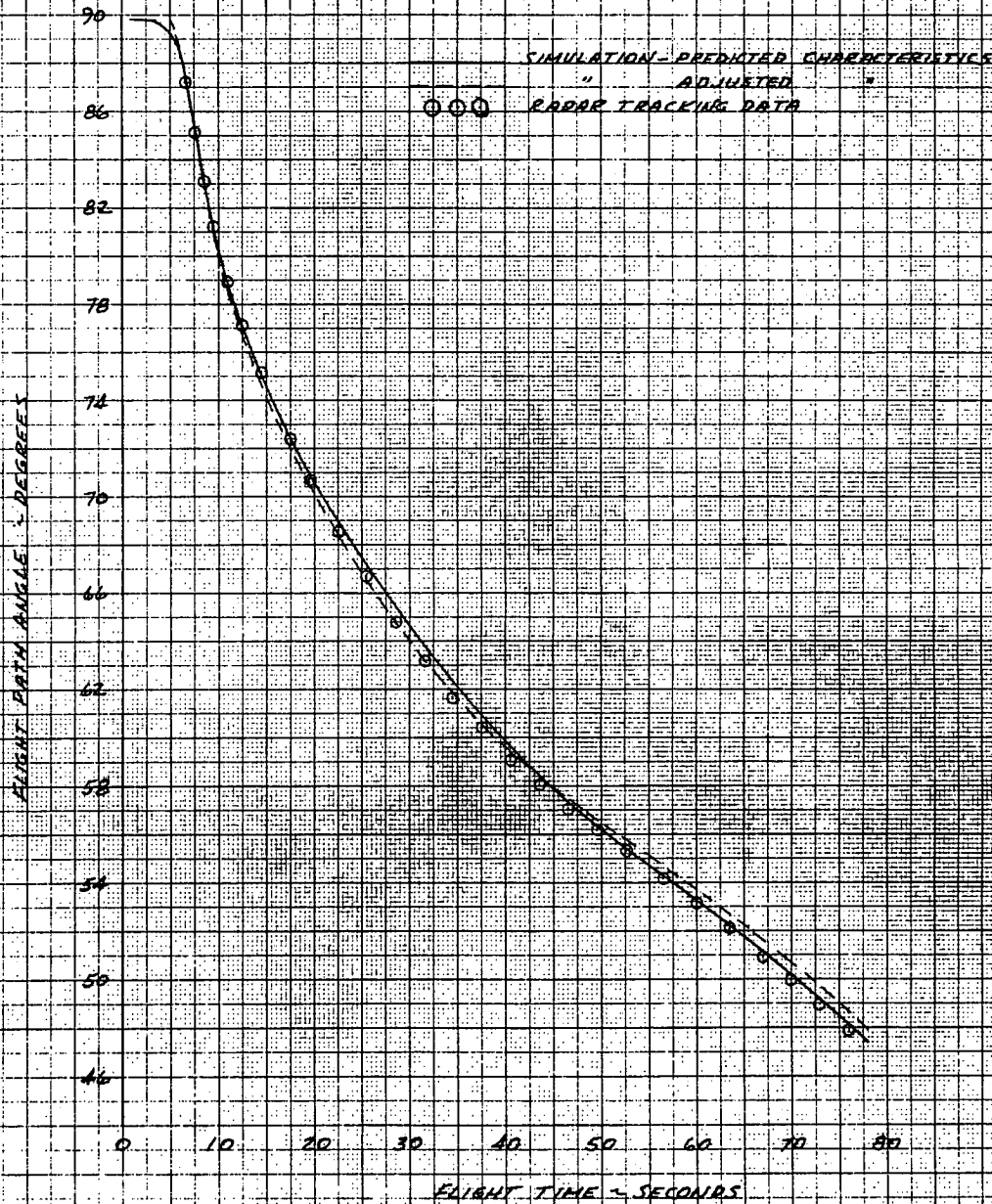


FIGURE 11C  
S-154 FLIGHT DATA COMPARISON CONT'D

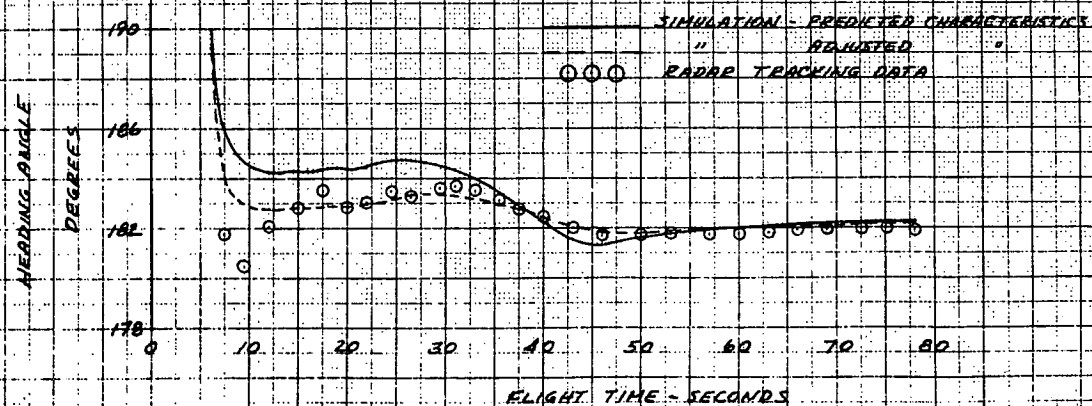
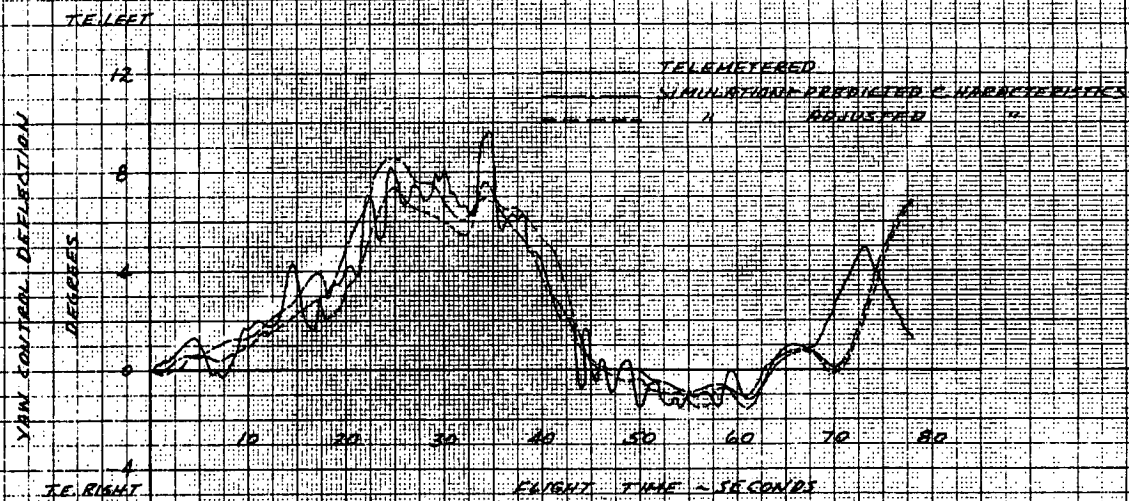
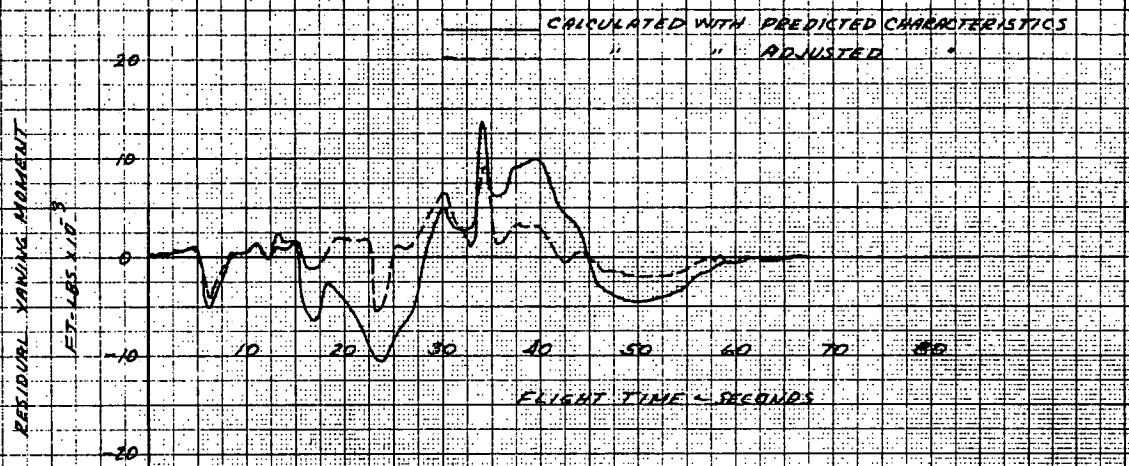


FIGURE 12a.

S-155 FLIGHT DATA COMPARISON

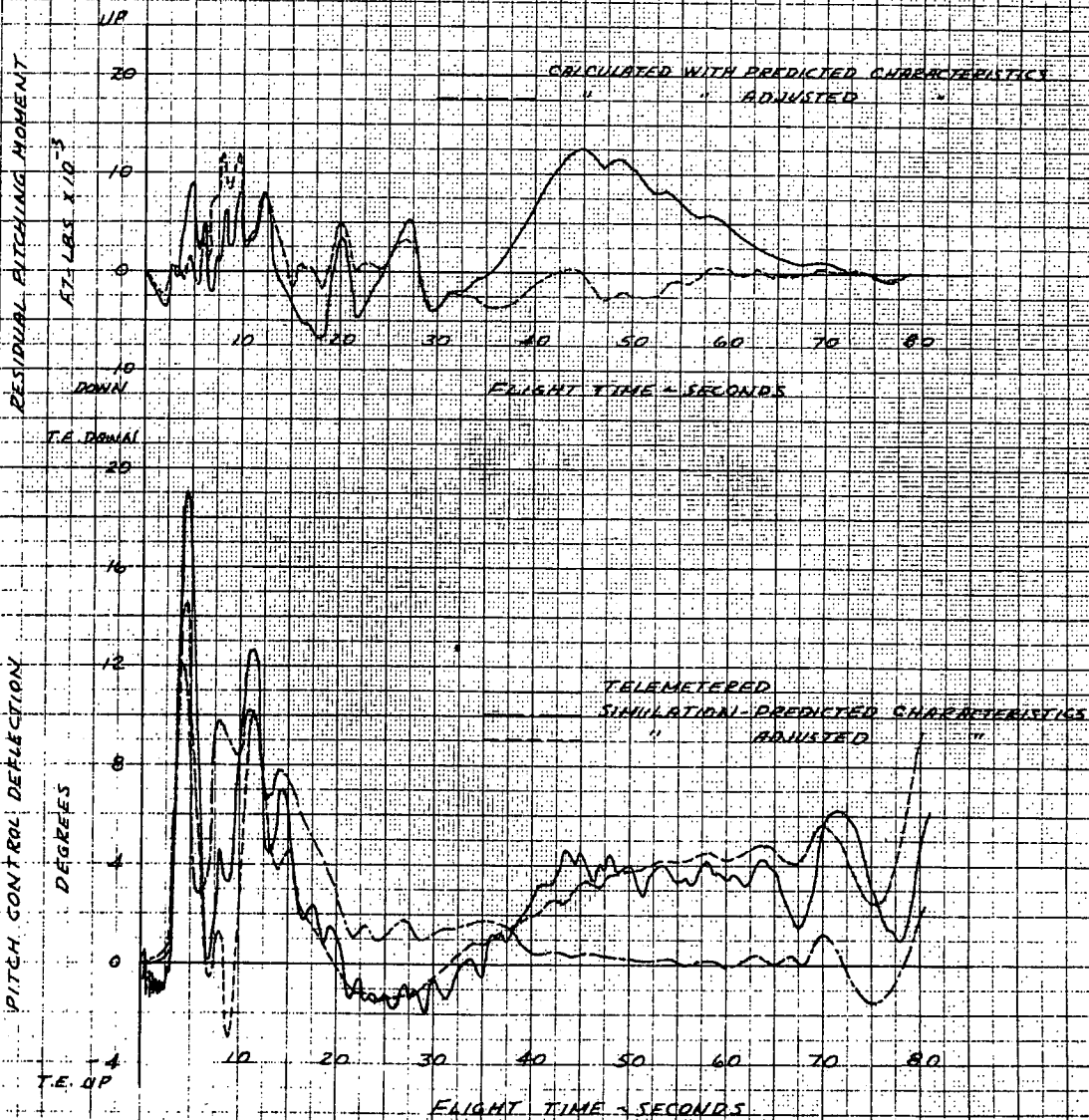




FIGURE 12 b  
S-155 FLIGHT DATA COMPARISON CONT'D

FLIGHT PATH ANGLE - DEGREES

FLIGHT TIME - SECONDS

— SIMULATION - PREDICTED CHARACTERISTICS  
" ADJUSTED " "  
○ ○ ○ ○ ○ RADAR TRACKING DATA

Flight Time (Seconds)	Flight Path Angle (Degrees)
0	90
5	88
10	84
15	78
20	72
25	66
30	60
35	55
40	51
45	48
50	45
55	42
60	40
65	38
70	36
75	34
80	32

S-155 FLIGHT DATA COMPARISON CONT'D

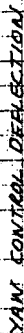
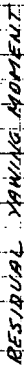




FIGURE 13a  
S-156 FLIGHT DATA COMPARISON

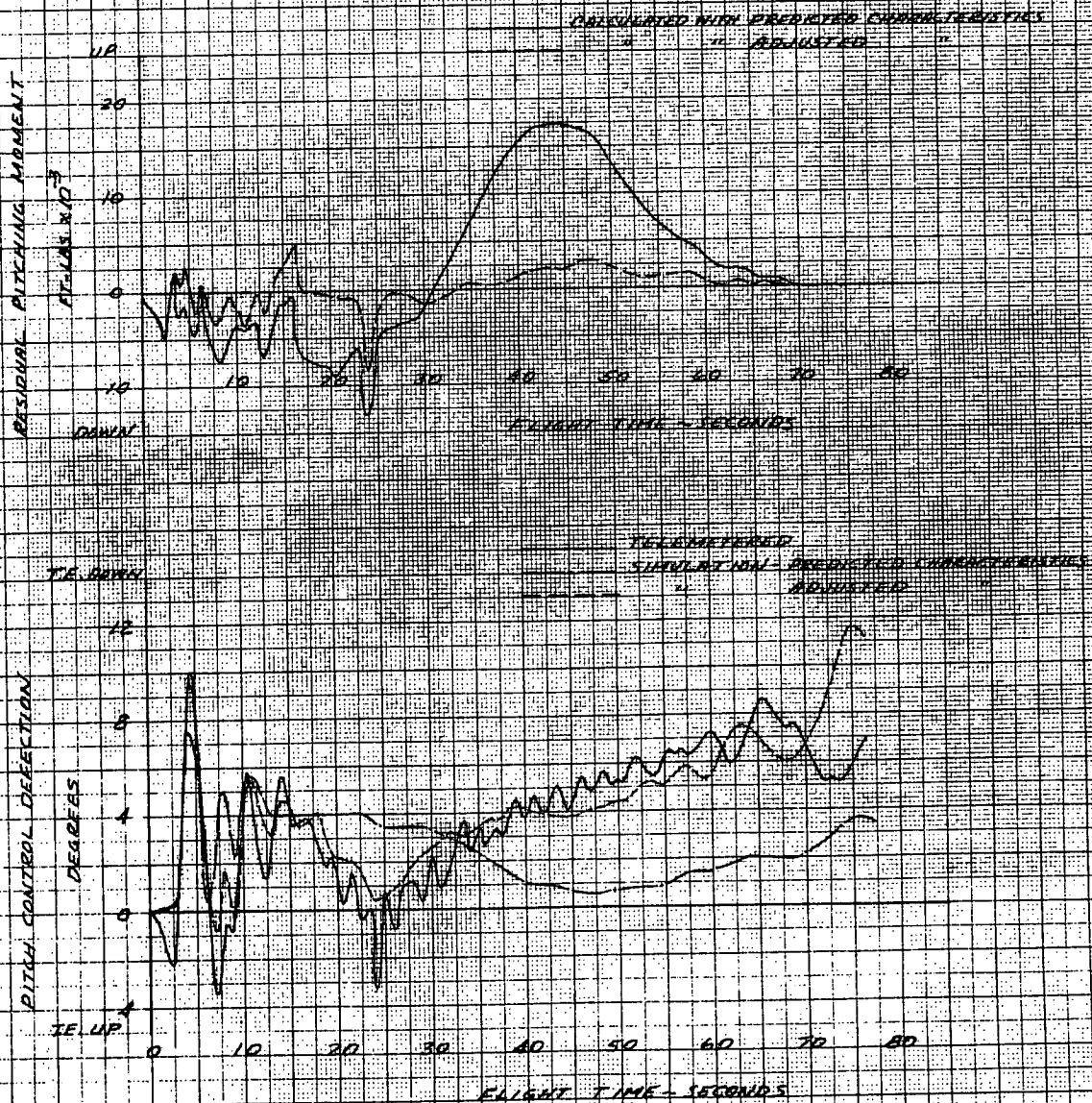


FIGURE 13.6  
S-156 FLIGHT DATA COMPARISON (CONT'D)

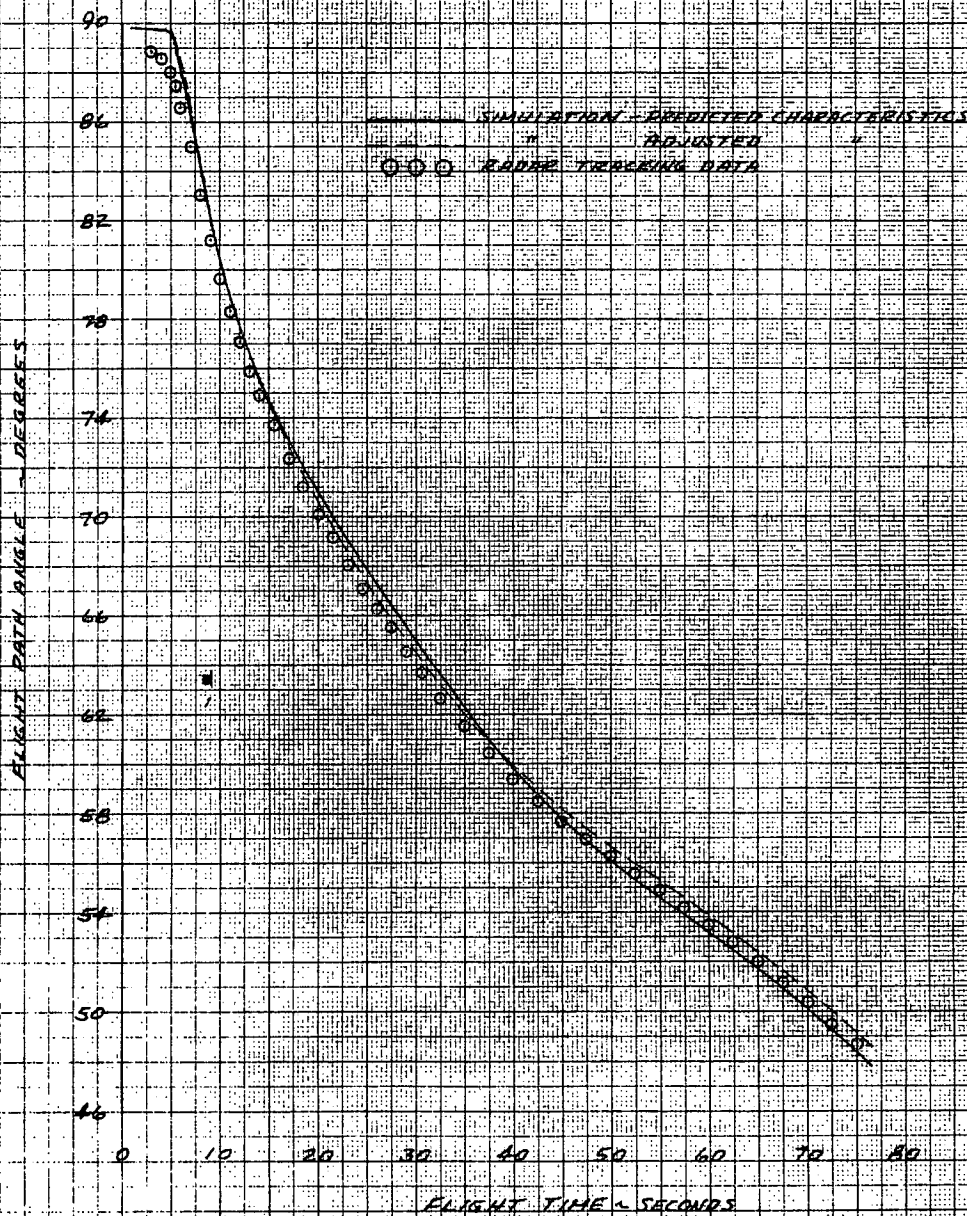


FIGURE 130  
S-156 FLIGHT DATA COMPARISON/ CONT'D

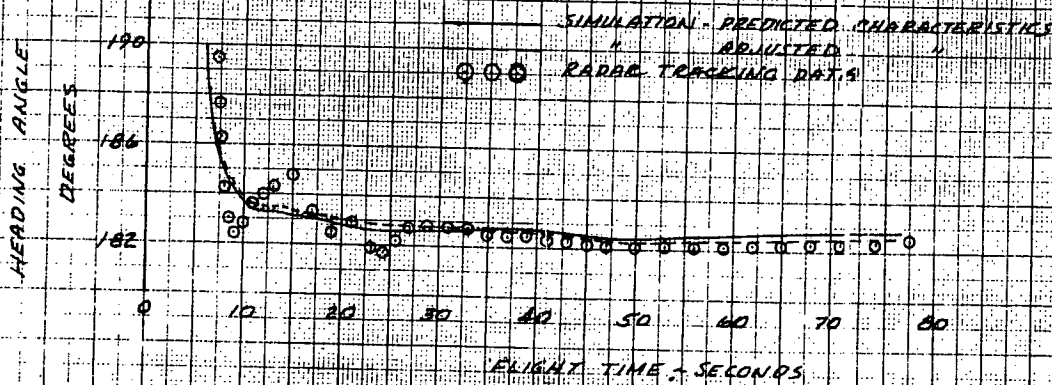
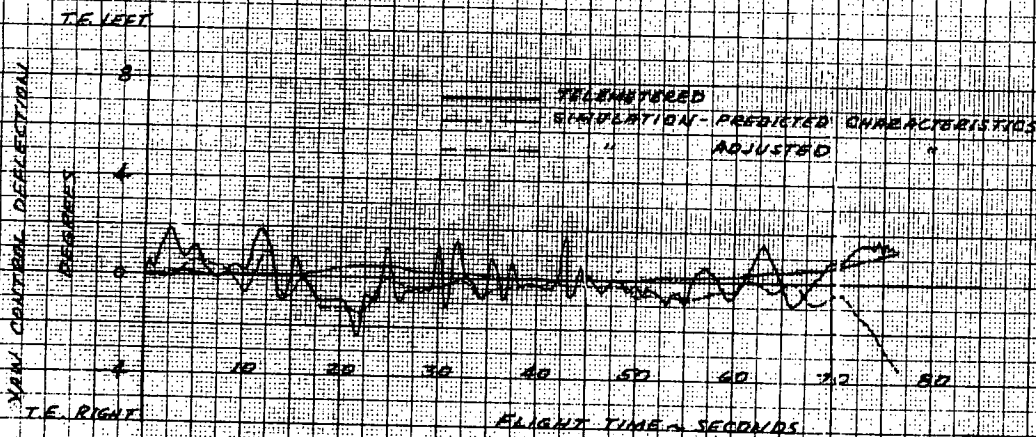
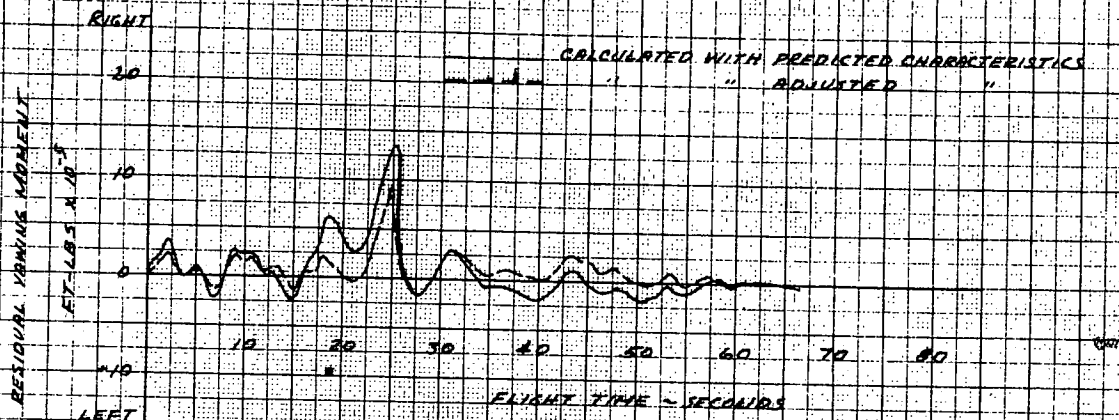
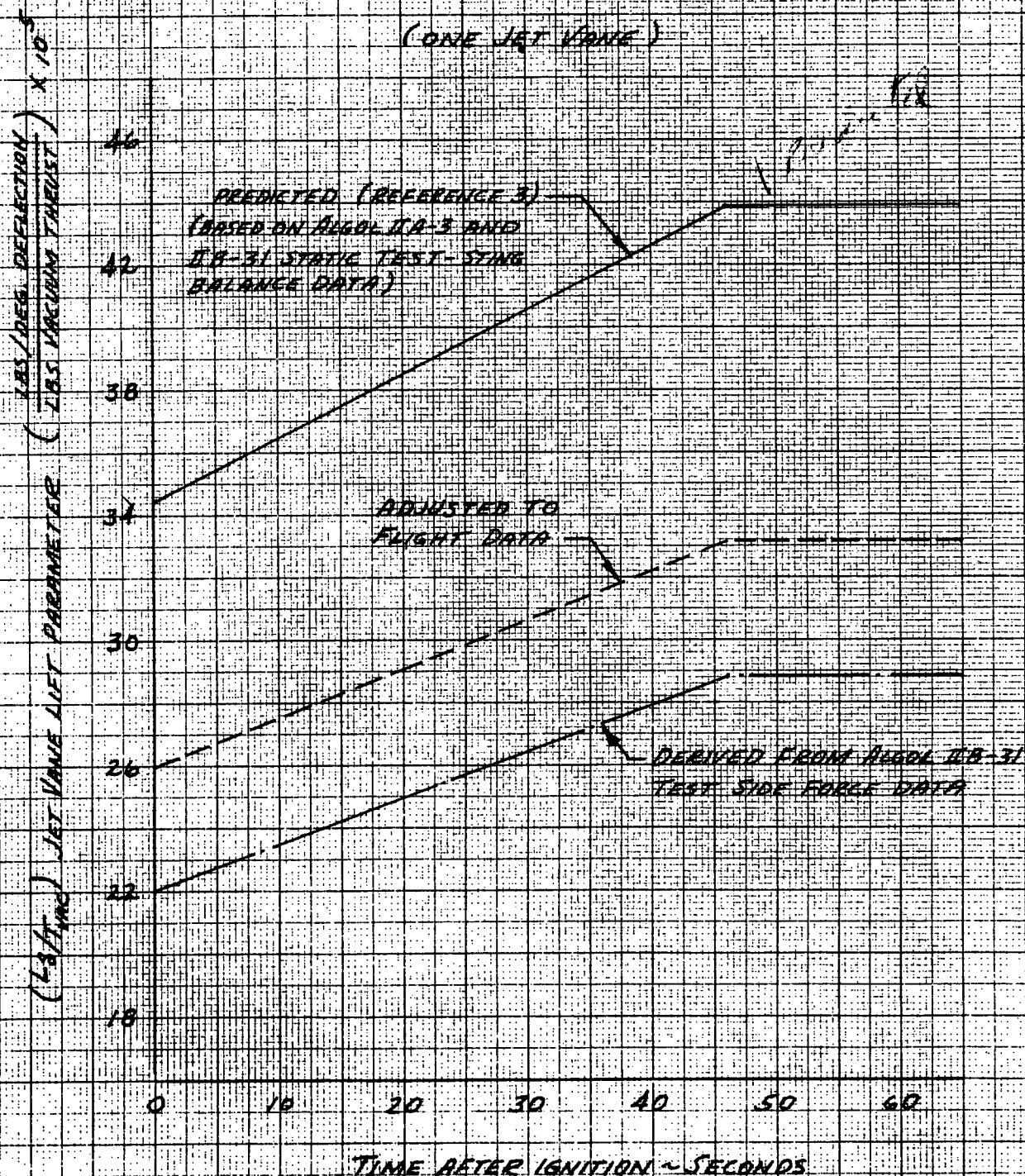


FIGURE 14

JET VANE LIFT EFFECTIVENESS VS. FLIGHT TIME





$C_{NS}$  OR  $C_{XS}$  FORCE (COEFFICIENT SLOPE ~ FT. PER DEGREE

FIGURE 15  
 NORMAL OR SIDE FORCE COEFFICIENT SLOPE  
 DUE TO DEFLECTING ONE CONTROL FIN TIP

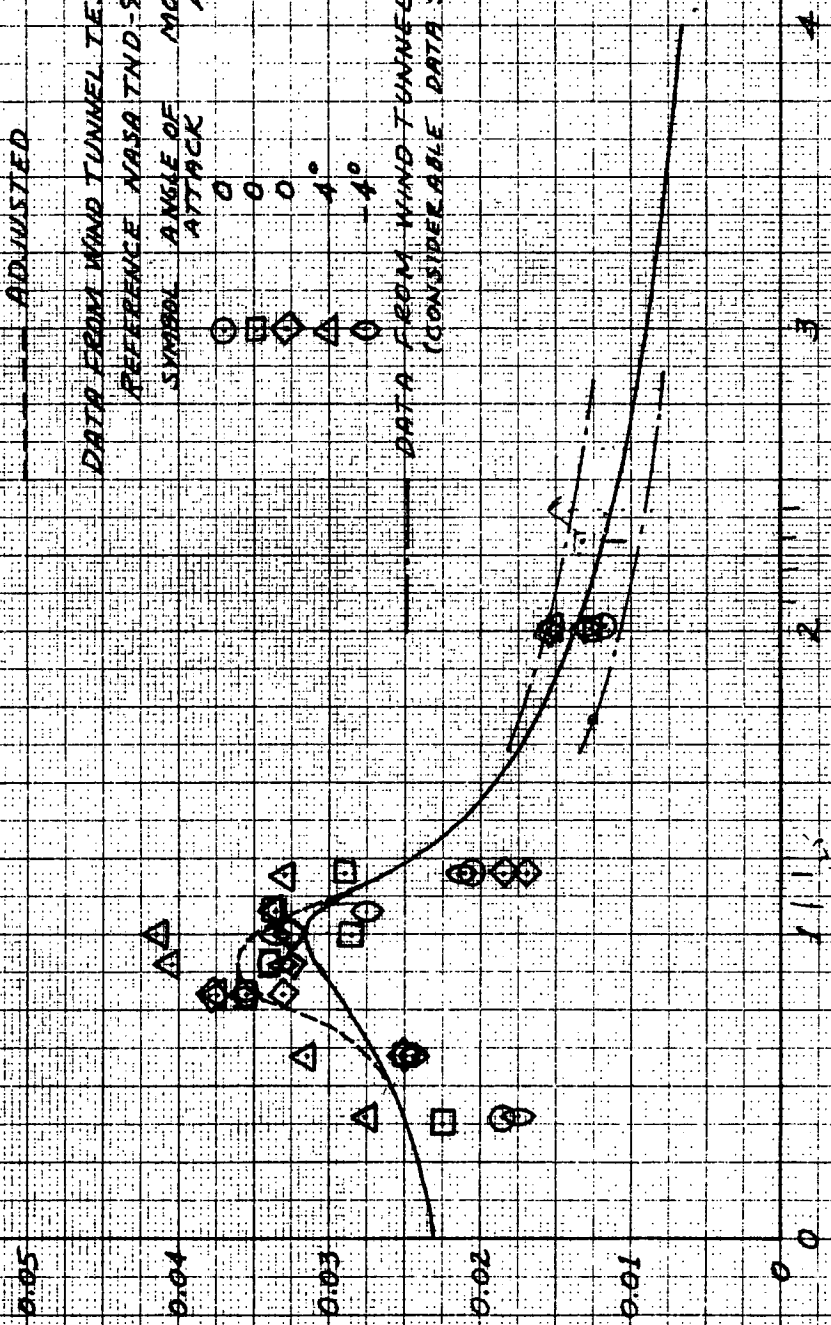
PREDICTED (REFERENCE 1)  
 ADJUSTED

DATA FROM WIND TUNNEL TESTS:

REFERENCE NASA TND-918 AND NASA TMX-239

SYMBOL	ANGLE OF ATTACK	MODEL ROLL ANGLE
○	0°	0°
□	0°	45°
◇	0°	90°
△	4°	0°
○	4°	0°

DATA FROM WIND TUNNEL TEST REF. 16  
 (CONSIDERABLE DATA SCATTER)

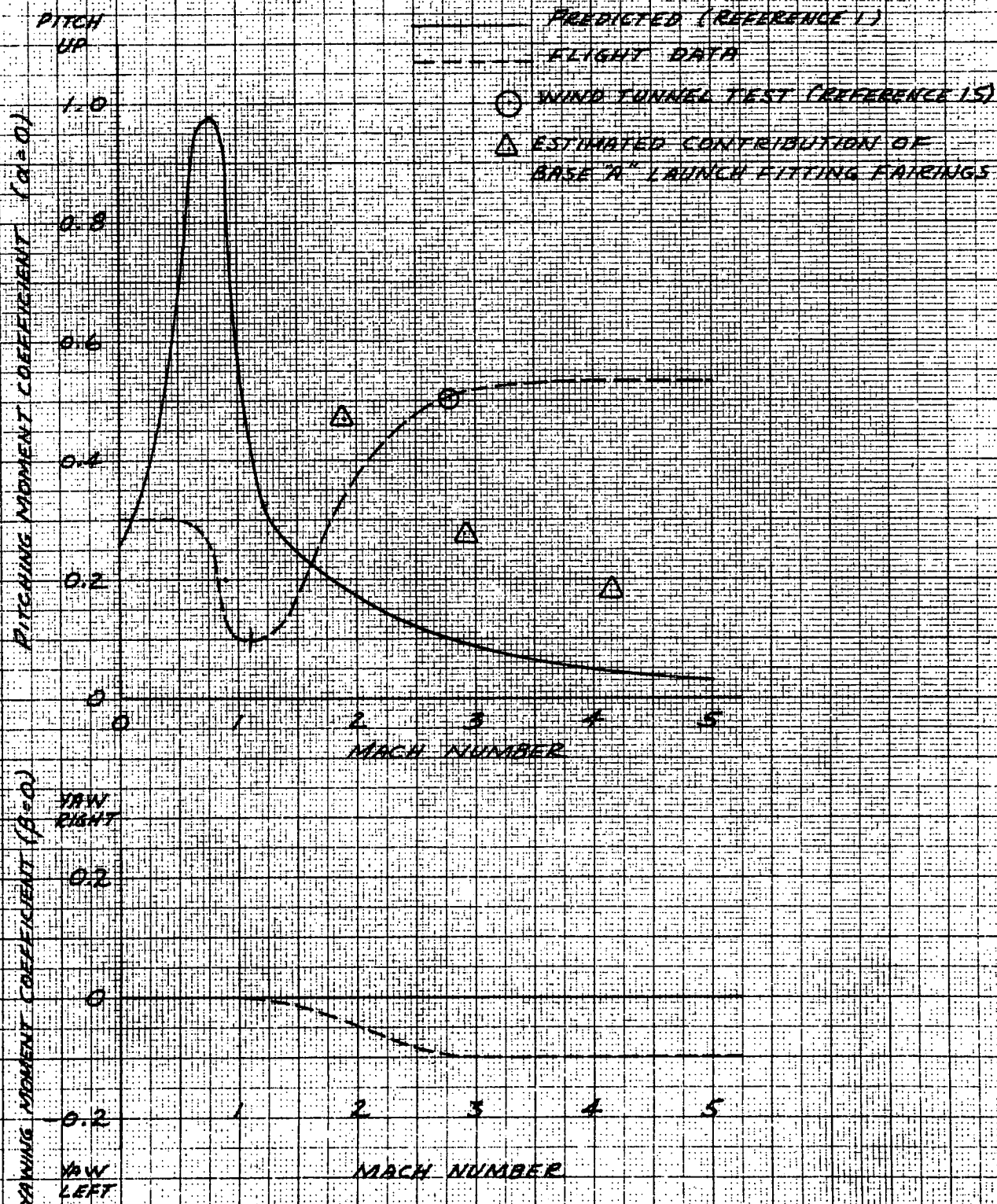


MACH NUMBER

FIGURE 16  
PITCHING AND YAWING MOMENT COEFFICIENT  
AT ZERO AERODYNAMIC ANGLE

$S_{REF} = 5.25 \text{ FT}^2$

$C_{REF} = 2.58 \text{ FT}$



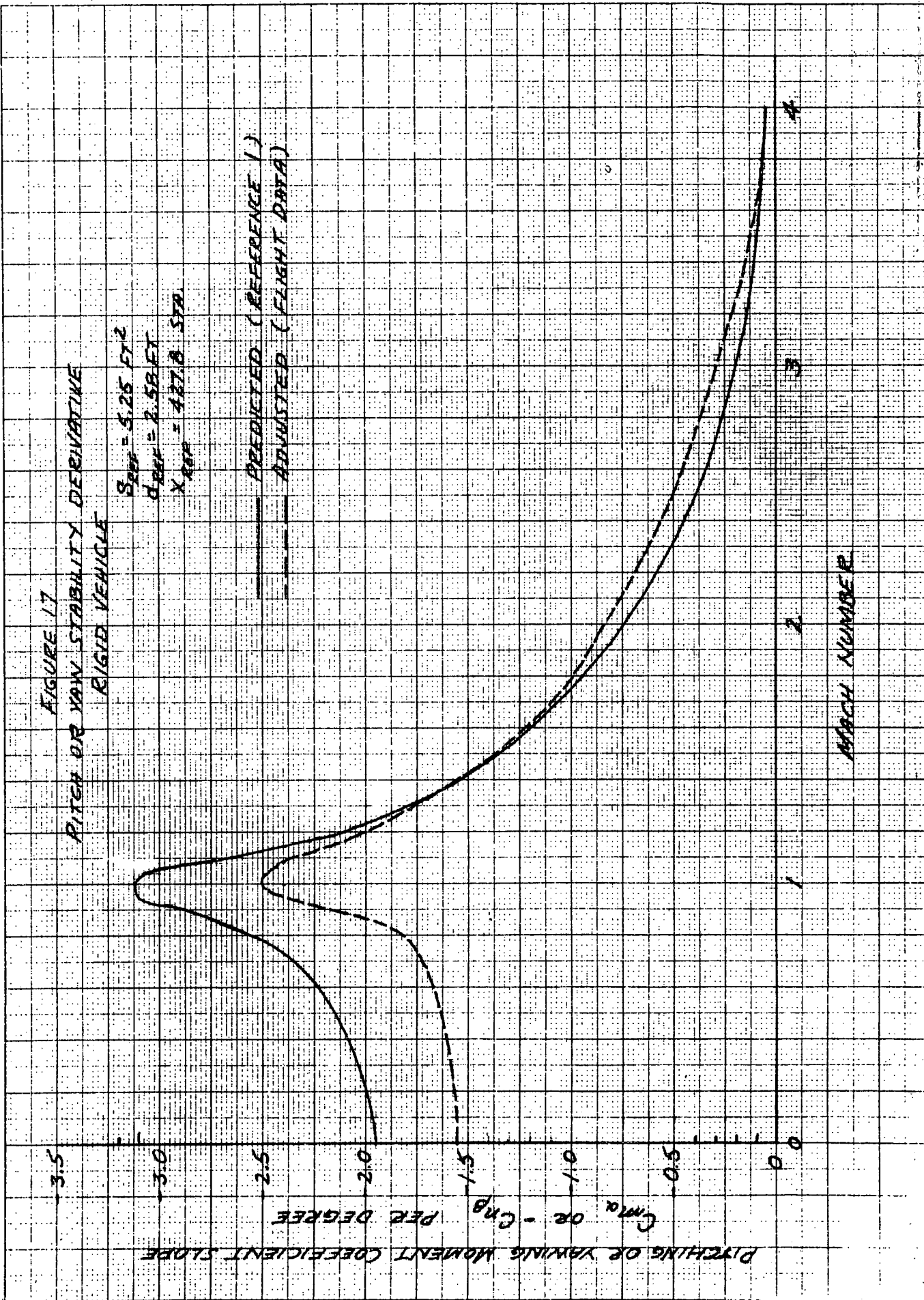




FIGURE 18  
 AERODYNAMIC CENTER OF PRESSURE LOCATION  
 RIGID VEHICLE

— PREDICTED (REFERENCE 1)  
 --- ADJUSTED (FLIGHT DATA)

BODY STATION

WING NUMBER

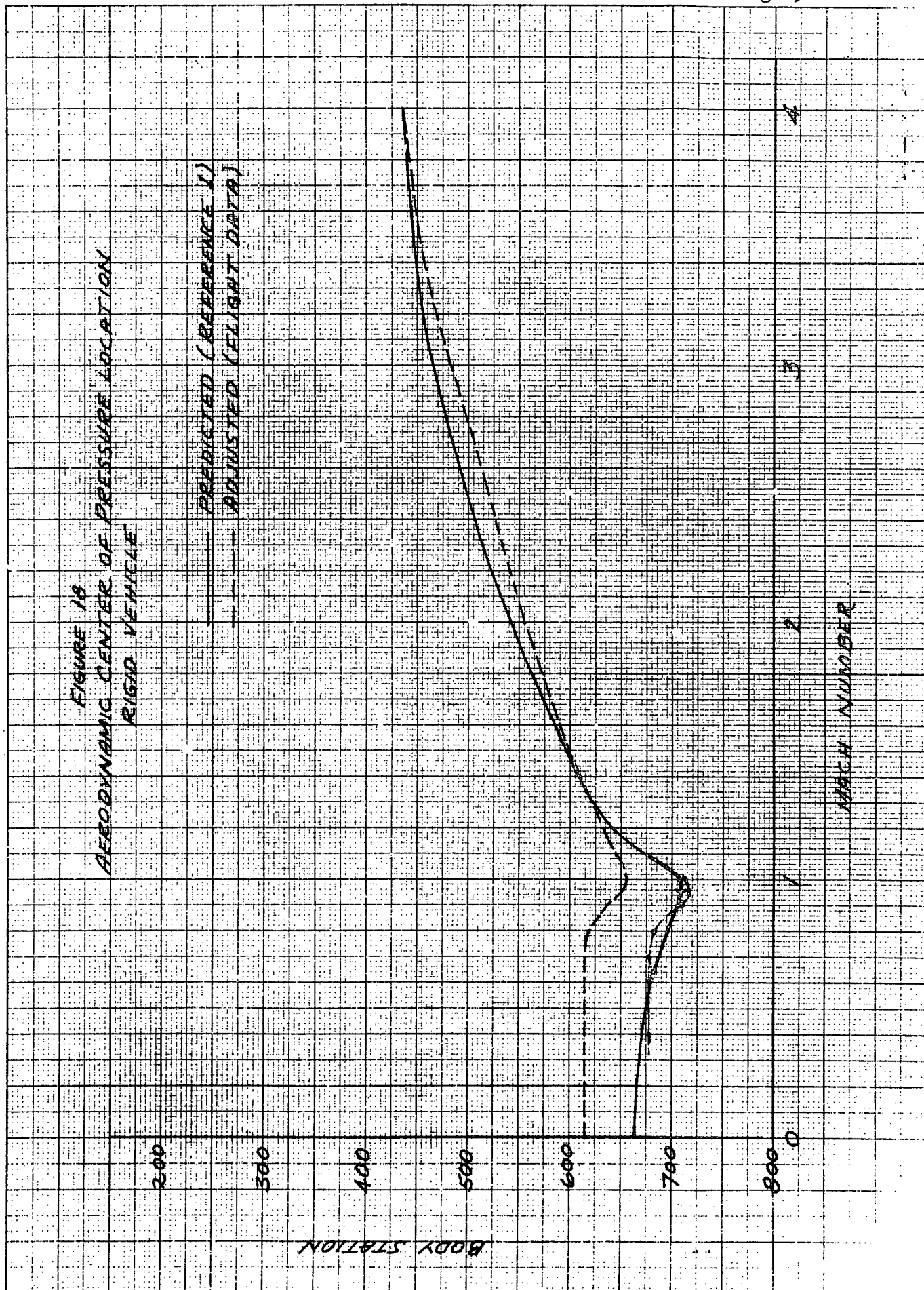


FIGURE 19  
FLIGHT PATH ANGLE AND NORMAL FORCE  
DEVIATION FOR SCOUT VEHICLE S-150

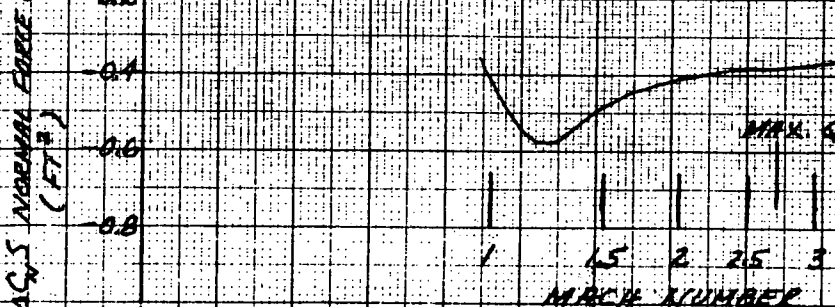
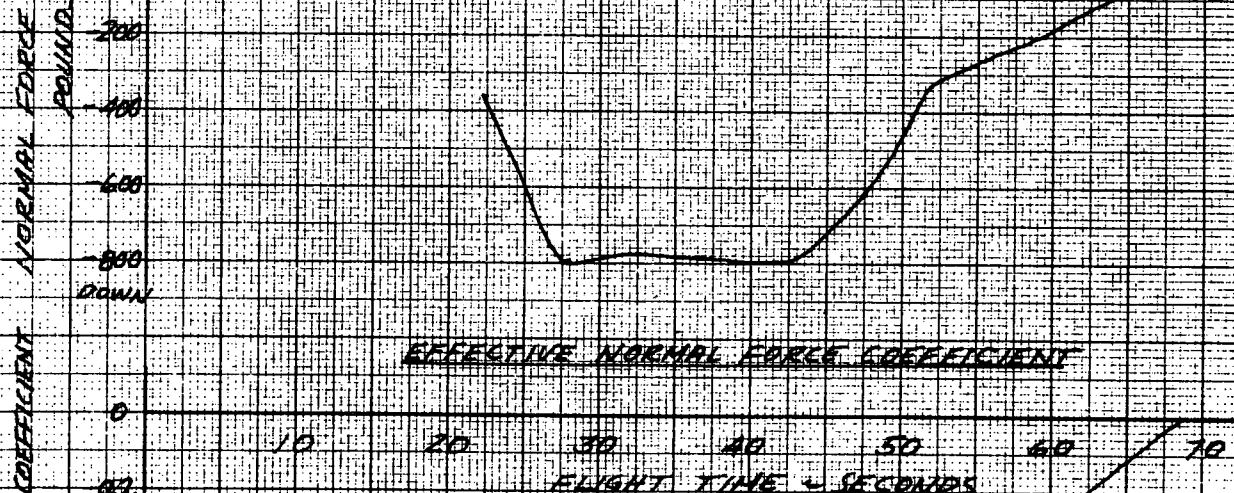
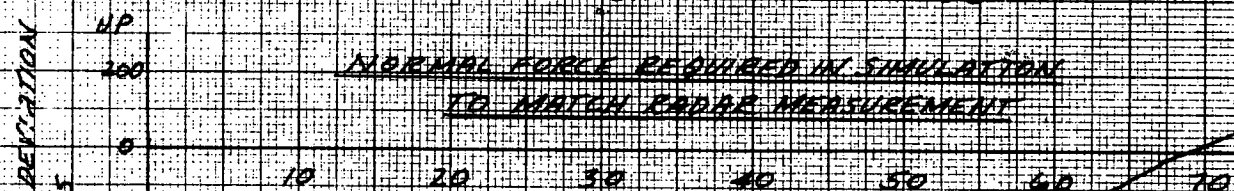
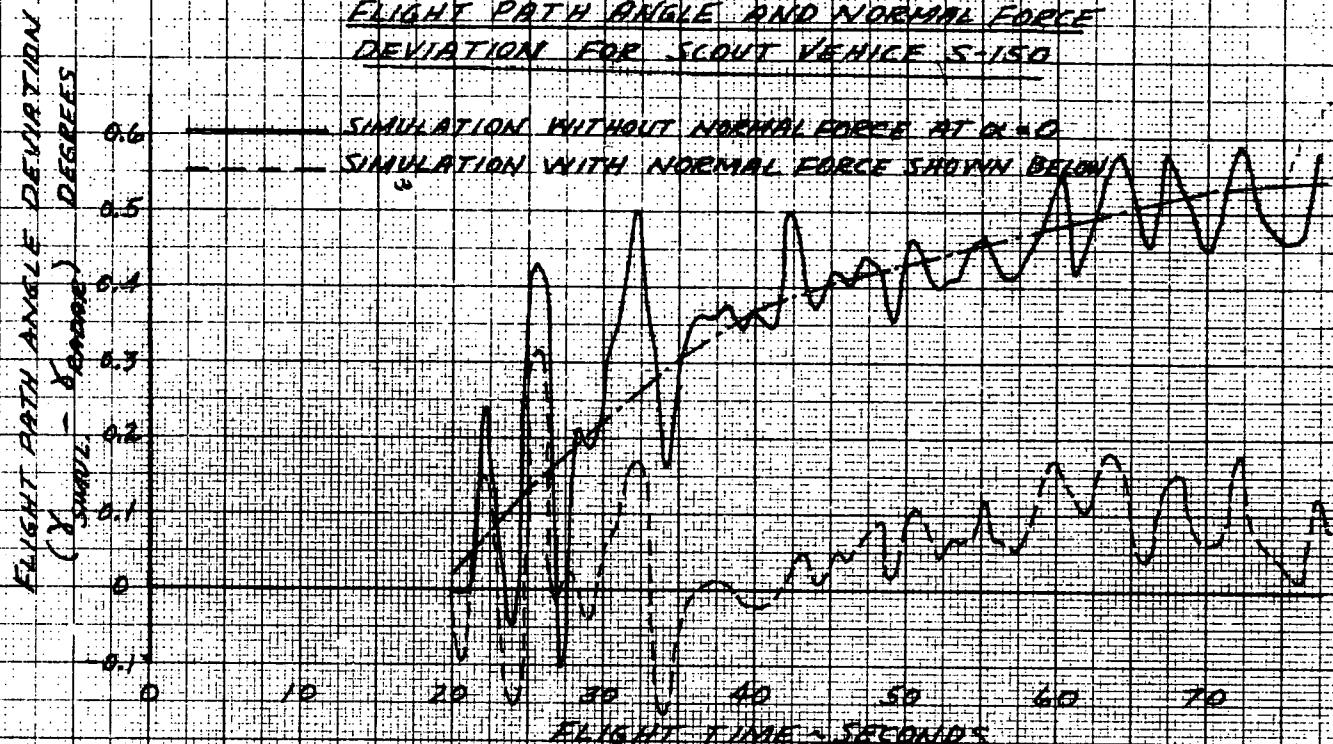


FIGURE 20  
VEHICLE S-152 MEASURED WIND PROFILES

